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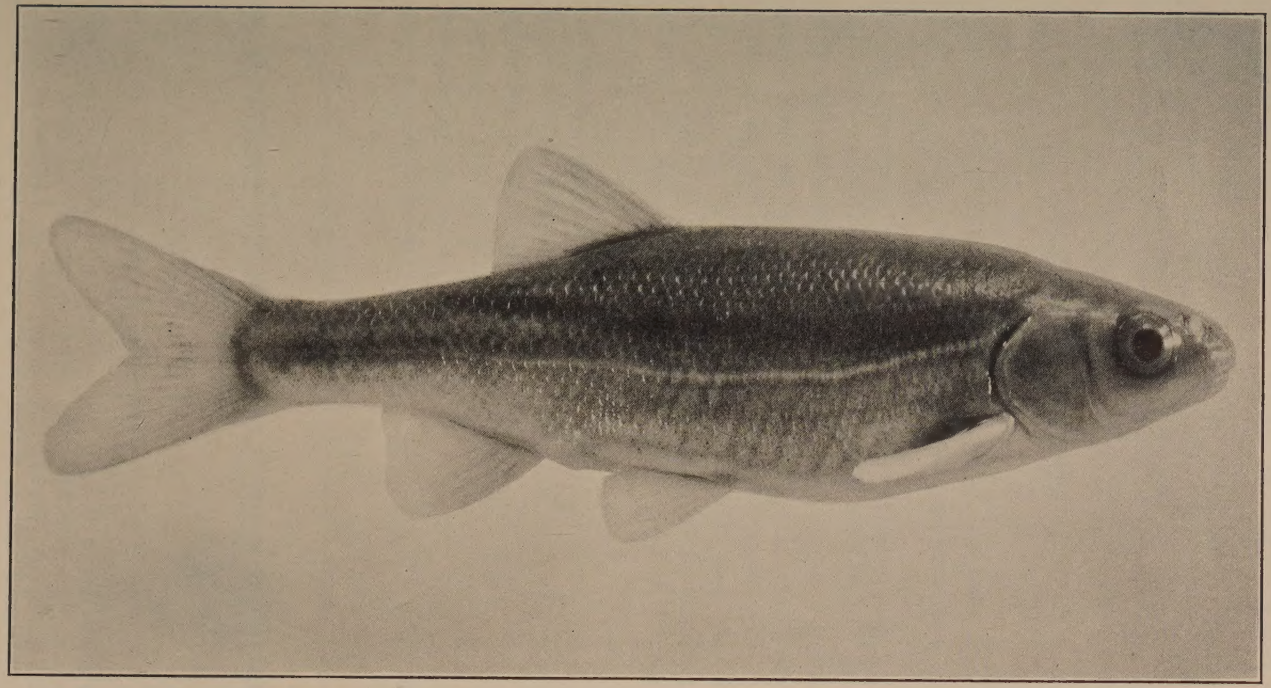

FIG. 25. *Hesperoleucus venustus* Snyder. Adult female, 70 mm., body length.

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LIFE HISTORY OF HESPEROLEUCUS VENUSTUS SNYDER

By DONALD H. FRY, JR.

INTRODUCTION

The fresh-water fishes of the western United States are already fairly well known. The species have been well described and their apparent relationships, in most cases, determined. Although there is undoubtedly room for extended investigation in this same field, it is safe to say that a detailed account of their habits and development would be of even greater value at the present time.

In work of this type, the commoner and more important species are obviously the ones which should be considered first, and as *Hesperoleucus venustus* Snyder is one of the commonest species in central California, it has been selected for this report.

The work on this paper was carried out at Stanford University under the direction of Professor J. O. Snyder. The material was collected in 1926 and 1927, and the report was finished in 1928.

SYSTEMATIC STATUS OF THE SPECIES

The earlier work on western minnows was, of necessity, rather superficial. This, combined with the great similarity of forms, frequently resulted in several genera being classed together as one genus or even as one species. Only one such case concerns this paper. A form once known as *Rutilus symmetricus* was reported from all of northern and central California and from parts of Nevada and Utah as well. As a result of later and more careful investigation it appeared that fishes of more than one genus, and certainly of several species, were included in this one nominal form.

A paper by Snyder on "The Fishes of Streams Tributary to Monterey Bay, California," clarified the situation in a measure. In this publication the generic name *Rutilus* was discarded, as it applied to a European minnow and was not available for American species not closely related to it. The name *Hesperoleucus* was substituted and made to include only certain fishes from the Sacramento-San Joaquin basin and a few coastwise streams. This new genus contained several more or less distinct forms which were given specific standing. Among these is *H. venustus,* of the Sacramento and Russian river systems, and streams entering San Francisco and Tomales bays.

SOURCE OF MATERIAL

Specimens from practically the entire range of the species were examined in the course of this investigation. The bulk of the material was taken from three creeks, descriptions of which follow:

Coyote Creek, Santa Clara County.

This stream rises in the Mt. Hamilton Range where it drains about 200 square miles in that vicinity before flowing into the Santa Clara Valley near the town of Madrone. After reaching the valley, its flow during the greater part of the year is underground, except at the extreme lower end where it reappears for a short distance and flows into the southern end of San Francisco Bay near the town of Alviso. The two portions of this creek are here described separately:

Upper Coyote Creek (in canyon east of the town of Madrone). It is from this area that most of the material for the present paper was taken. The stream, at this point, consists of a series of short rapids connecting large, shallow pools about 3 feet in depth and ranging from 20 to 50 feet in width and 100 to 600 feet in length. The banks are steep, root-grown, and average about 4 feet in height.

Parts of the stream are deeply shaded, but the greater portion is fairly open. The bottom consists mostly of gravel and rocks; sand

is rare and mud almost entirely lacking. During the winter months the stream flows bank full; by spring, however, the tops of many gravel bars begin to appear and by midsummer most of the pools are reduced to about half their winter area. Toward the end of the dry season (about October or November) the water is confined to hollows under the banks and to some of the deeper holes.

Species of fish present are *Hesperoleucus venustus* and Sacramento "pike" (*Ptychocheilus grandis*), in about equal numbers; suckers (*Catostomus occidentalis*) are slightly less abundant. These three species form over 99 per cent of the fish present. Sculpin (*Cottus gulosus*) and rainbow trout (*Salmo irideus*) form the rest. One larval specimen of *Orthodon microlepidotus* (a minnow) was taken during the course of this investigation.

Lower Coyote Creek (near mouth). Here the stream flows sluggishly between 15-foot banks, with 3-foot secondary banks confining the water except during flood periods. The stream is well shaded. The bottom consists of gravel, sand and mud. The flow of water is exceptionally uniform throughout the year.

Fish present: *Orthodon microlepidotus, Hesperoleucus venustus, Ptychocheilus grandis,* and *Gasterosteus cataphractus* (sticklebacks) are exceedingly abundant. Nearly all the lowland fishes of the Sacramento Basin are occasionally found here.

Guadalupe Creek, Santa Clara County.

This stream flows parallel to Coyote Creek, but is in the hills on the opposite (west) side of Santa Clara Valley. It also passes through the lower part of the valley and enters San Francisco Bay about a mile from the mouth of Coyote Creek. The part here described is situated in the hills about two miles north of the town of Almaden.

It is an exceedingly open creek flowing through a narrow valley. As a rule the banks are sharply defined on only one side. The pools, during the winter months, are 10 to 15 feet wide, 30 to 60 feet long, and up to 2 feet in depth, with occasional deeper holes of 4 to 5 feet. The bottom is gravel except in the deeper holes, some of which contain sand and mud. There are a few shelves of hard clay.

About May the water stops flowing and from then until the winter rains, the stream is practically dry except for occasional pools which soon begin to choke up with pond scum.

Species of fish present: *Hesperoleucus venustus, Catostomus occidentalis, Gasterosteus cataphractus,* and a few *Cottus gulosus.*

San Anselmo Creek, Marin County.

The part most carefully studied is inside the town of San Anselmo. In this locality the country is well wooded and the vegetation along the creek bank keeps the water in almost complete shade throughout the greater part of its length. The stream is narrow, with banks about 15 feet in height. The pools are rarely over 50 feet long, 15 feet wide, and 2 feet deep, and are sufficiently brushy to make seining difficult. The bottom is gravel with occasional banks of hard clay. There is no period of excessive dryness. In most places the water *flows* throughout the year.

Fishes present: *Salmo irideus, Hesperoleucus venustus, Oncorhynchus kisutch* (silver salmon), *Gasterosteus cataphractus,* and *Catastomus occidentalis* are the common species.

FOOD HABITS

During their larval growth, laboratory specimens of *Hesperoleucus* were fed catches made with a fine mesh tow net. These included diatoms, unicellular algae, cyclops, and other minute organisms. All of these were eaten readily by the developing fish. Stomachs of wild larvae contained principally diatoms. In all probability those were all that did not digest.

Small fish (under 40 mm.) appear to be almost wholly carnivorous. The bulk of the food was found to consist of crustaceans and aquatic insects. Almost any animal matter is accepted. A small percentage of diatoms was always found, but it is probable that these were accidentally included.

Larger fish (over 40 mm.) were found to be carnivorous so long as there was no *Spirogyra* present. As soon as this began to grow in any quantity, they would include large amounts with the animal part of their diet. In late summer, when the pools were rather crowded, the larger fish would eat almost nothing except *Spirogyra.* In all probability it was the only food present in quantity. Whether it was eaten for its own food value or for the micro-organisms with which it teems, is problematical.

Probably the smaller fish are not strong enough to tear out bunches of this *Spirogyra* and are forced to forage among the strands for whatever small organisms are present. The larger individuals include these with the plant material.

SPAWNING

The fish when spawning are quite shy so that it is very difficult to get within 10 or 15 feet of them. The writer was exceedingly fortunate in finding a school spawning directly under a very low bank which was covered with long grass. The grass formed almost perfect cover and permitted observation at a distance of about two feet.

After milling about excitedly in deep water for an unknown period of time, the fish begin to congregate on the chosen spawning ground. All the fish which are spawning in a pool at one time do so in an area perhaps three feet in diameter. Frequently they are so tightly packed that they form an almost continuous layer of splashing bodies. This splashing makes the fish quite conspicuous but does not interfere with their wariness.

The female finds a deep crack between two rocks and squirts her eggs into it. The male sometimes lies beside her and ejects his milt while she is depositing her eggs, but usually there is so little space between the rocks that only one fish can operate at a time. This leads to a continual struggle, as the males keep crowding in. It is probable that great benefit to the species results from this struggling, as it tends to keep the female from laying too many eggs in one place, with consequent suffocation. The eggs, being exceedingly adhesive, stick firmly

to the under side of the rocks and are in no danger of being washed away.

SEASON

The spawning season in any one creek appears to last about two months. The time at which the season starts seems to depend largely upon the temperature of the water. In an open, sunny creek in a warm district, spawning may commence as early as the middle of March; whereas in a heavily shaded stream near the coast it may occur six or seven weeks later.

The approximate season in several different streams is as follows:

Guadalupe Creek	March 15–May 15
Coyote Creek	April 1–June 1
San Anselmo Creek	May–_____
Russian River (near Ukiah)	_____–July 1

The approach of the spawning season is indicated by the appearance of nuptial coloring on the adult fish. This consists of patches of orange or scarlet at the bases of the anal, ventral and pectoral fins; on the opercles, and corners of the mouth and chin. These colors are found on both males and females. At this season the males have, in addition, numerous minute pearl organs on top of the head. In a few cases the colors begin to be noticeably bright about four months in advance of actual spawning and remain a month or two after the close of the season. There is no season of the year at which a few individuals (usually males) do not have traces of this coloring.

NUMBER OF EGGS SPAWNED

A female *Hesperoleucus* lays several hundred eggs, each about a millimeter and a half in diameter. A very small female (55 mm. in length) contained 250 ripe eggs, an average one of 75 mm. had 600, and large specimens of 85 and 95 mm. contained about 800 and 900 ripe eggs, respectively.

SPAWNING GROUNDS

The spawning of *Hesperoleucus* takes place without any migration, the eggs being deposited either in the home pool or within a few yards of it. The spawning ground is located in flowing water ranging, so far as observed, from a depth of four inches to that of less than an inch. It may be in broken water or in smooth, provided there is enough current to keep silt from settling. The chosen spot is where the bottom is covered with rocks an inch or two in diameter and where there are not enough smaller particles to fill in the spaces between the rocks.

HATCHING

Only once was the writer fortunate enough to be present at both the spawning and hatching of a batch of eggs. The incubation period in this case was 10 days.

The larvae, in hatching, break through the egg membrane with their tails and then go through rapid, swimming motions until they free themselves. A considerable mortality occurs at this time, due to

the yolk sac sticking to the egg "shell" and rupturing as the fish tear themselves away.

Immediately after hatching, the larvae hide in crevices between the stones. Occasionally one will wiggle out, swim upward an inch or so, and sink to the bottom again. The current may carry a larva several inches when it makes one of these dashes; thus this habit serves to disperse the larvae more rapidly than would be the case if the eggs hatched in still water.

The habit of worming into small spaces is undoubtedly an advantage in a stream where there is running water and plenty of oxygen. In a battery jar, on the other hand, it resulted in the loss of half the fish present. These had evidently gotten into spaces where there was no circulation. This difficulty was overcome by leaving so little gravel in the bottom of the jar that there were no longer any closed spaces.

Larvae can be collected at this stage by stirring the gravel to start them moving, noting where one comes to rest, and sucking it up with a barley straw or piece of glass tubing.

Artificial hatching was attempted in various ways. Stripping the fish, followed by artificial fertilization, proved a total failure as no eggs even started segmentation. Artificial hatching of newly laid eggs produced very little better results. The eggs were left stuck to the rocks and the latter placed in a battery jar into which a steady stream of tap water flowed. Fungus soon began to attack the eggs and although the affected ones were immediately removed, only three out of a hundred escaped and developed to the point of hatching. It is possible that the fungus was aided by the darkness of the room in which the eggs were kept. By waiting until a batch of eggs had developed to the point where the eyes of the embryos could be clearly seen, and then transferring them to battery jars, about 98 per cent of those taken were hatched. These eggs, curiously enough, had been deposited in less than an inch of water and even though the creek dropped about three inches, they had gone on developing in the moist places under the rocks.

LARVAL DEVELOPMENT

Among larval *Hesperoleucus* the various organs begin to develop as the larva reaches a certain size, rather than a certain age.

The ages here referred to are those of specimens raised in a battery jar. Under these conditions, larval growth was completed in 13 weeks. In a stream, however, larvae may develop in as short a time as 8 weeks or may take as long as 14 weeks. This should be borne in mind when reference is made to the age at which various organs appear.

The size given at different stages of development are for both wild and laboratory specimens, there being no difference between the two in this respect. Regardless of external conditions, larval development lasts until the fish has reached a length of 16.7 mm. (the range found was from 15.8 to 17.7 mm.). The first appearance of scales is considered by the writer to constitute the termination of the larval period.

NEWLY HATCHED LARVA

The newly hatched larva (see Fig. 26, A) is about 5 mm. long,[1] and if the yolk sac is excluded, about 0.7 mm. deep. About two-thirds of this depth is a fin fold which extends from about half a millimeter forward of the anus, around the tail to a point on the back about 1 mm. in advance of the vent. The body rests on a large spherical yolk sac which has a narrow stem extending back almost to the anus. The head is slightly decurved, the eyes are small and have pigmented retinae. There is no other pigment on the body. No external trace of mouth or gills can be found. The pectoral fins are present as minute buds. There are no other fins and no fin rays in the fold.

At this stage, the gut is a narrow tube showing only the faintest sign of an opening in its center. It passes from the future location of the mouth backward and upward to the top of the yolk sac and then back to the anus in a groove in the top of this sac.

The heart is placed just in front of the yolk sac and is slightly below the lower edge of the eye. The sinus venosus is in a cone-shaped depression in the yolk sac and is about the same size as the heart itself. The fish has, in hatching, uncoiled itself from the yolk sac. In so doing, it has lifted its head and formed a space between the still decurved head and the sac. The aorta has been pulled into this space. A thin membrane stretches from the head to the yolk sac, covers this space, and streamlines the anterior end of the fish.

The brain can be distinctly seen in cleared specimens and is so little protected that its general outline can be discerned even when the larva is in alcohol. The otocysts, which are as yet simple ovoid sacs, can be seen slightly above and posterior to the eyes. The notochord is perfectly straight for the posterior three-fourths of its length; the anterior one-fourth is slightly decurved.

Respiration is carried on through the broad fin fold. The larval habits being what they are, there is a decided benefit in having this process carried on at the posterior end, as the larvae wiggle down into the gravel head first, thus leaving the tail nearest the oxygen supply. This does not seem to be a factor of any importance until it is considered that there is always a slight amount of mud, slime, and algae between the grains of gravel. With the large yolk sac serving as a plug, these could easily seal the front half of a larva away from an ample oxygen supply. The fish at this stage are exceedingly sensitive to a lack of air. Even in perfectly clean gravel in a battery jar, many of them will die if the water is not kept running.

DEVELOPMENT OF THE DIGESTIVE TRACT

The yolk sac, which is at first nearly spherical, within a few hours becomes elongated into a narrow cone, the point of which is posterior. It reaches from the pectoral fin almost to the anus and has a diameter of about one-fourth its length. It becomes narrower as it is absorbed, but remains about the same length until its contents have become almost

[1] Length measurements given in this paper are taken from tip of the snout to the tip of the hypural bone. In larval specimens where the hypural had not yet formed, the tip of the notochord was used instead. This measurement is hereafter referred to as "body length."

exhausted. The yolk supply lasted from 10 to 14 days in laboratory specimens.

When the yolk has become absorbed to such an extent that the sac is about one-third the dorso-ventral diameter of the body, the gut is still a narrow functionless tube. From this point on, as the yolk disappears the gut expands and fills in the space, thus keeping the abdominal cavity about the same size and shape. Towards the conclusion of this process, the fish begins to feed. During the expansion of the gut, the liver is undergoing a similarly rapid development.

The gut remains practically straight until the fish is about 10 mm. long and is 9 or 10 weeks old. About this time it begins to form its first coil. From this time on, the development of the gut is rapid. In another three weeks it reaches the adult stage, in which it is coiled to such an extent that it reverses its direction five times between mouth and anus.

DEVELOPMENT OF RESPIRATORY SYSTEM AND AIR BLADDER

For the first three days, the larval *Hesperoleucus* respires almost entirely through the well-vasculated fin fold. (See description of newly hatched larva.) At the end of this time the gills make a very sudden appearance. At first they are not covered to any appreciable extent by the opercles. (See Fig. 26, B.) The reason for this is that the mouth is still closed. Whatever water comes in contact with the filaments must reach them from the outside. At the age of about a week, the air bladder appears and the fish leave the bottom permanently. About this time the mouth opens, thus enabling the gills to function to better advantage.

From this time on, the opercles gradually begin to grow and cover the gills. At the age of about one month the air bladder has begun to divide and only a slight fringe of gill filament projects beyond the opercular flap. When the fish is six weeks old, the gills are completely covered, as by this time the opercles and branchiostegal membranes are practically in adult form. (See Fig. 26, B, C and D.)

DEVELOPMENT OF FINS

The only fins present at the time of hatching are the pectorals, which appear as minute buds. At the end of about three days they have grown into a pair of stalks, each with a pointed distal blade. As development continues, the stalks become shorter and the blades longer and wider until, at three weeks, the fins are roughly the shape of the adult pectorals and are proportionally about three-fourths their size.

In the median fin fold a slight narrowing can be first noticed in the caudal peduncle region at the age of about one week. At this time there is a slight up-tilt to the tip of the notochord and the membrane is beginning to thicken slightly in the location soon to be occupied by the caudal rays. These begin to appear in another three or four days and are at first directed downward, as the notochord is not yet sufficiently upturned to permit them to point straight back.

At an age of from three to four weeks, the first trace of the dorsal fin appears. (See Fig. 26, C.) Here, as in the case of the caudal, this consists of a thickening of the fin fold. At this stage the caudal may be

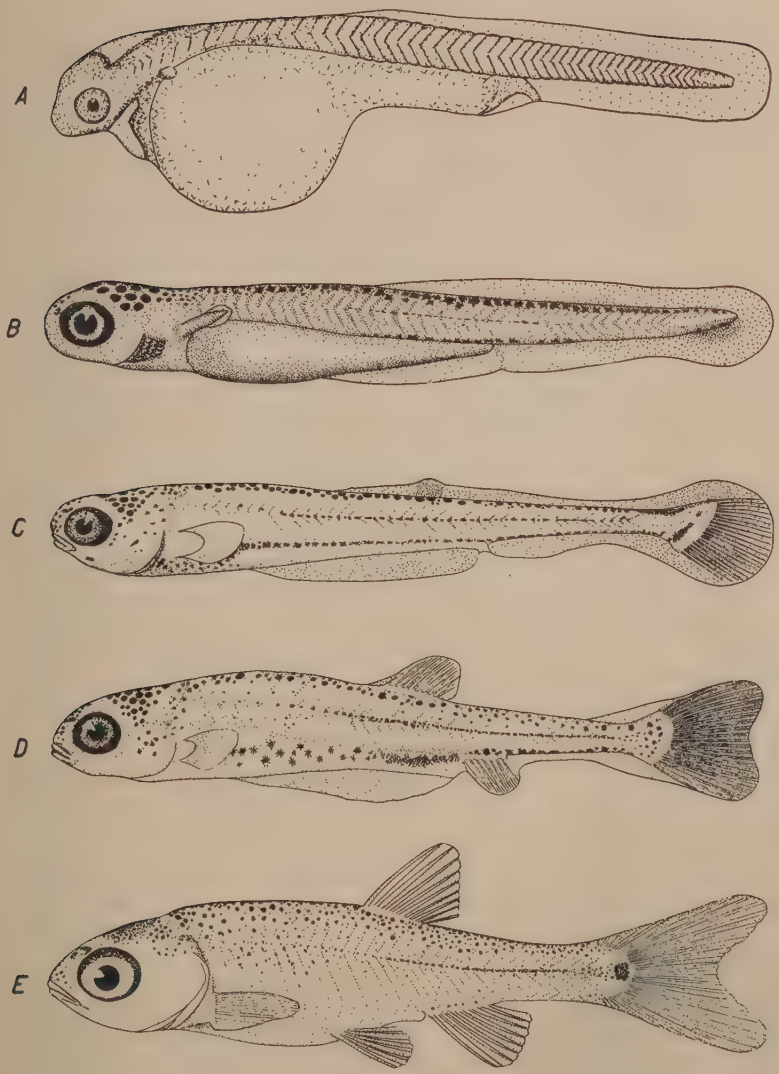

FIG. 26. Larval stages of *Hesperoleucus venustus*.

A—Newly hatched larva, 5 mm., body length. At this stage there is no external sign of mouth or gills and no pigment except in the retinae of the eyes.

B—Three-day larva, 6½ mm., body length. External gills have appeared but the mouth is still closed, although traces of it can be seen from a ventral view which is not shown.

C—Larva, 8½ mm., body length. The mouth is open, gill filaments are almost covered by opercles, and the first trace of the dorsal fin is forming.

D—Larva, 9½ mm., body length, with dorsal and anal fin rays.

E—*Hesperoleucus venustus*, towards the close of larval development, 14 mm., body length.

rounded, flattened, or even slightly lunate. In another week all the dorsal rays have formed and the anal is becoming discernible.

By the time the fin fold has disappeared, the caudal is lunate and the dorsal and anal fins are beginning to assume a resemblance to those of adults. (This stage is slightly more advanced than that shown in Figure 26, D. The fish at this time are six or seven weeks old.

In another two or three weeks, the ventral fins appear as minute buds. By this time the larva (though only 10 mm. long) has begun to resemble an adult fairly closely in body shape and fin proportions.

DEVELOPMENT OF PIGMENTATION

The newly hatched larva, as previously mentioned, is unpigmented except for the retinae. This condition lasts only a few hours, however. At the end of three days the young fish has, dorsally, about 30 round spots on the head and a double row of chromatophores distributed about one pair to each muscle segment. The ventral surface is somewhat more lightly spotted. Internal pigmentation is also found at this stage, there being numerous chromatophores on the dorsal surface of the body cavity. When the air bladder appears, at about one week, it is heavily pigmented. By this time the dorsal surface of the gut and the branchial arches have become quite well outlined.

The mid line formed by the union of the dorsal and ventral muscle bands begins to be faintly pigmented as early as the second or third day. Throughout the larval development of the fish, more and more pigment is added to this line, especially on the posterior half. This process continues until there is formed a broad band which persists throughout life. This should not be confused with the lateral line which, when it appears, lies in the band for the posterior quarter or third of the body, ventral to the band for almost all the remainder, and then meets or crosses it just back of the operculum.

As the larva develops, there is a tendency toward a rounding out of the chromatophores into sharply defined spots. This change takes place far more slowly on the ventral surface of the fish and is followed by a vast increase in the number of spots and a corresponding reduction in the proportional size of the largest ones. The process continues until the fish gives the appearance of being shaded rather than spotted.

As the first caudal rays form, they are sharply outlined in black, and small spots begin to form both on the fin and the caudal peduncle. The lateral band at this stage is clearly defined for its posterior half; much less so for the remainder. When the dorsal fin first begins to appear, about a week later, there are numerous small spots on the snout, cheeks and sides. Ventrally, the pigment is still mainly confined to rather stringy chromatophores. Dorsal fin rays, shortly after they appear, are pigmented, although less heavily than those of the caudal. Other fins are even lighter than the dorsal.

At, or shortly before, the first appearance of the ventral fin buds, there develops at the base of the caudal a large black spot which tapers into the lateral band. Two other spots, large and heart-shaped, appear about the same time on the top of the head. The smaller of these occupies most of the space between the eyes and is pointed anteriorly. The other, pointing in the opposite direction, extends from immediately behind the eyes to a point above the base of the pectoral

fin and then blends into a narrow line which extends the entire length of the back. All of these markings persist throughout life, though they may become faint with age.

The fish, during the last two or three weeks of its larval life, is shaded in much the same manner as the adult, but except for the above mentioned spots and bands, is much lighter. This, of course, causes these bands to stand out much more sharply than in later life.

When scales first appear, there is a tendency for pigment to outline them and thus indicate the scale pattern. This sometimes persists even into the second year, but usually more pigment is added in such a way that within a month all traces of this pattern have been obliterated.

APPEARANCE OF SCALES

Scales appeared in the laboratory specimens at an age of 13 weeks. Under natural conditions, this may take place in from 8 to 14 weeks. The size of the larva at the time of scale appearance is 16.7 mm. ($\pm$ 1 mm.). Formation and development of scales will be discussed later at length.

DEVELOPMENT OF PHARYNGEAL TEETH

Up to the time the fish has reached a length of 14½ to 15 mm., the pharyngeal bone is slender and round. In a specimen of 15½ mm. it was decidedly flattened and somewhat wider than before. A 16 mm. individual had a pharyngeal bone on which slight bumps indicated the future position of the teeth. From 17 mm. on, the fish were found to have a complete set of teeth.

SUMMARY OF LARVAL DEVELOPMENT

Age		Length to base of caudal
Hatching:	Yolk sac spherical Gills and pigment absent No external indication of mouth	5 mm.
3 days:	Yolk sac conical External gills present Large chromatophores on head, back and belly Internal pigment present Lateral band of pigment just starting Mouth appearing externally; still closed	6½ mm.
1 week:	Much yolk remaining Air bladder appearing Mouth opens	7 mm.
2 weeks:	Yolk gone; feeding begun Caudal rays starting Gills covered by opercles	8 mm.
3–4 weeks:	Caudal rounded, flat or slightly lunate Dorsal fin appears Pigment becoming more finely divided	8½ mm.
4–5 weeks:	Air bladder dividing Caudal slightly lunate Dorsal rays complete Anal forming	9 mm.
6–7 weeks:	Fin fold disappearing Anal fin complete	9½ mm.
9–10 weeks:	Gut coiling Ventral fin buds present Other fins of adult shape Pigmentation similar to adult, but lighter	10 mm.
13 weeks:	Larval development complete Scales present Pharyngeal teeth present Gut coiled	17 mm.

SCALES

Scales are first formed as minute discs early in the life of the fish. As the fish grows the scales increase in size but not in number. The most striking feature of scale growth is the addition of material to the edges in the form of more or less concentric ridges. Seasonal variation in the spacing and appearance of these ridges often makes it possible to determine the age of a fish from its scales.

For convenience, a list of terms generally used in describing scales follows:

Annulus: Place in year's growth of a scale where circuli are crowded most closely together. Sometimes takes form of a check.

Apex: The end of the scale farthest from point of attachment, *i.e.*, the one towards the posterior end of the fish.

Apical angle: The angle formed by the edge of the scale at its apex.

Apicolateral angle: The angle formed between the apical and lateral edges of the scale.

Basal angle: The angle at the base of the scale.

Base: The end at which the scale is attached, *i.e.*, the one nearest the head of the fish.

Basolateral angle: The angle between the basal and lateral edges of the scale.

Check: A place where scale growth has stopped entirely and then started again. Circuli inside a check are usually not concentric with those outside that check.

Circuli: Ridges which are formed more or less concentrically about the focus.

Focus: The central disc of a scale.

Radii: Grooves in the scale radiating outward.

Regenerated scales: Scales which have replaced those lost.

DESCRIPTION OF SCALES OF ADULT FISH

Scales from Side of Fish.

The shape of the scales of *Hesperoleucus* varies greatly with age and with the part of the body from which the scale is taken. The following description of the adult scale and of the changes brought about by age refers only to scales taken from the side of the fish, anterior to the vent. The scales upon which measurements are based were taken from just above the lateral line, immediately anterior to the dorsal fin.

The scale of an adult fish is roughly hexagonal. The basolateral angles are well marked, the apicolateral ones less so. The latter become, in general, more strongly marked with age, though in some fish as old as three years there is no trace of them. In such cases the posterior angle is usually lacking as well, so that the dorsal, ventral and posterior sides all form one smooth curve. The anterior side is formed by two edges which may be convex or straight, but which are usually slightly concave. These edges meet in a rounded point at an angle of about 120°. (See Fig. 27, A.)

Out of 100 fish of over 30 mm., body length, the largest variation in the shape of a scale was 7 per cent from the average. This was calculated by obtaining the average length-width ratio for that size of fish and for the scale in question. The greatest difference was 7 per cent of the average. Care was taken to obtain a normal appearing scale from each fish.

Scales from Other Parts of Body.

Caudal peduncle scales are about 1.5 times as long as they are wide and are about 0.9 as long as the largest of those found on the side of the fish. Basolateral angles are strongly marked. Apicolateral angles are distinct. Dorsal and ventral edges are straight or nearly so, converging anteriorly. The posterior edge is usually well rounded, though not enough so to eliminate the posterior angle but some times the angle is quite sharp. (See Fig. 27, B.)

Dorsal scales are smaller than lateral ones, but are about the same shape or slightly more rounded. (See Fig. 27, D.)

Scales taken from the belly of the fish are far smaller than lateral scales and are proportionately about 15 to 20 per cent narrower. (See Fig. 27, E.)

Due to the pores in them, lateral line scales are wider than their neighbors.

FIG. 27. Scales from a 96 mm. third year male, *Hesperoleucus*, taken in Coyote Creek, August 2.

A—Lateral scale.
B—Caudal peduncle scale.
C—Scale from immediately behind opercle.
D—Dorsal scale.
E—Ventral scale.

Scales from immediately behind the opercle are shaped much like a capital D. The anterior edge is concave, curved to fit the edge of the gill opening. The length is slightly less than that of a lateral scale, while the width is about 1.5 times as great. The length of these scales is only 0.6 of their width. (See Fig. 27, C.)

At the base of the caudal fin the scales are spatulate (shaped like the blade of a shovel).

A few spatulate scales are scattered all over the body.

Scales which have grown together are occasionally found.

The turning of a scale in its pocket, or some other accident, may result in a scale of unusual shape.

Radii.

The radii of *Hesperoleucus* scales are in general restricted to the posterior field, nearly all being confined to the space between the apico-lateral angles. About one fish in five has a few short lateral radii. These occur more often in larger specimens and are usually found at the margin of the scale. When present near the center of a scale, lateral radii nearly always terminate at an annulus instead of reaching the margin. In fish from Russian River, lateral radii are the rule rather than the exception.

A fish which has lateral radii on *any* of its scales, will have them on practically every scale. The distribution is by individual *fish*, not by individual scales.

DEVELOPMENT OF SCALES FROM SIDE OF FISH

Scales are first formed as minute circular or very slightly elliptical discs, about 0.13 mm. in diameter. When they are elliptical, the long axis is vertical. (See Fig. 28, A.)

The first circuli destroy the even circular shape of the scale, as only about a third as much scale material is added on the anterior edge as on the remainder of the scale. This slow growth of the anterior field continues through life. Its effect is to change the shape of the scale to a rough approximation of an ellipse with the long axis running vertically. More than a superficial resemblance to an ellipse is destroyed by the presence of two distinct basolateral angles and a basal angle.

In general, the more slowly a fish grows the more pronounced is this change in scale shape, though all specimens show it to some extent. When a fish has reached a body length of 22 mm., the largest scales from a given individual measure about 0.28 x 0.45 to 0.40 x 0.45 mm. and average 0.36 x 0.45 mm. About this time the posterior field of the scale starts growing more rapidly. This increase makes up for the slowness of the anterior field, so that the longitudinal axis starts growing at almost the same rate as the dorso-ventral one. By the time the average fish has reached 45 mm., body length, the scale measures 1.02 x 1.15 mm. The actual difference between the length and height has increased slightly (0.04 mm.) but the proportional difference has decreased. The shape of the scale is approaching a circle. If a check is formed in the growth of the scale while the fish is between 35 and 55 mm., body length, the posterior field abruptly begins an even more rapid growth immediately after the formation of this check. (See Fig. 28, E

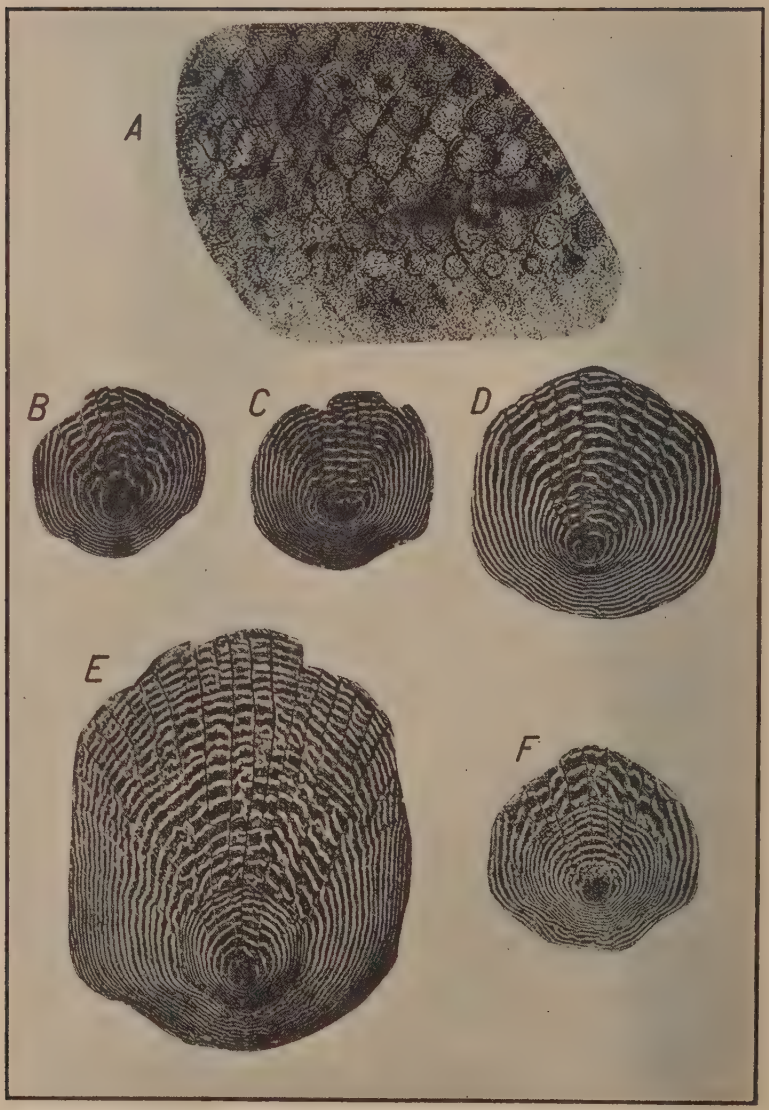

FIG. 28. Scales from *Hesperoleucus*.

A—Skin of young fish with first scales just forming.
B—Scale of 40 mm. fish in first year. Coyote Creek, October 25.
C—Scale of 50 mm. male at end of first year. Coyote Creek, May 13.
D—Scale of 55 mm. female at end of second year. Coyote Creek, May 13.
E—Scale of 85 mm. female at end of second year. Coyote Creek, May 7.
F—Scale of 56 mm. male at end of second year. Coyote Creek, May 13.

and F.) If no check is formed within this range, the same speeding up occurs, but the acceleration is more gradual. From this time on, the length of a scale increases more rapidly than the width. For an average fish of 55 mm., body length, the two scale dimensions are equal; for larger individuals, the length is greater. By the time the fish has reached 80 mm., a typical scale measurement is: length, 2.42 mm.; width, 2.17 mm. The ratio is roughly 1.1 to 1.

These changes in scale shape are correlated with both size and age, though more markedly with the former. Very rapidly growing fish do not seem to deviate from the average in the matter of scale shape. Stunted individuals, on the other hand, have scales of a shape which is normal for a certain size of fish before that size has been reached, showing that age plays a definite part in this case.

REPLACEMENT OF LOST SCALES

When a scale is lost, a disc of scale material somewhat smaller than the entire original scale is deposited in its place. This disc has a rough, crinkly surface instead of being smooth as is the central disc of a normal scale. Scale material is added to this disc much more rapidly than on a normal scale and the circuli are of wider spacing. This rapid growth continues until the new scale is nearly normal in size.

SCALES AS AN INDEX OF LIFE HISTORY

Choosing the field of scales to examine in order to obtain life history data is a separate problem with each species. In *Hesperoleucus*, both the anterior and posterior fields are quite unsatisfactory. In the former region, the circuli are so crowded together that it is almost impossible to distinguish anything. In the posterior portion, on the other hand, the circuli are widely spaced but many marks which are distinct on the other three-quarters of the scales are faint or totally indistinguishable here.

The lateral fields have neither of these disadvantages and prove to be entirely satisfactory. The circuli are fairly widely spaced and show detail far better than in the other two regions.

What scales to choose for age determination does not seem to be a matter of vital importance, so long as no regenerated ones are used. In general, the larger scales are easier to read.

First Appearance of Scales.

The scales of *Hesperoleucus venustus* make their appearance when the fish is about 16.7 mm. in body length.

Of 100 specimens between 14 and 19 mm., the smallest with scales measured 15.8 mm. and the largest without, 17.7 mm. in body length. Half of these fishes were from Coyote Creek; the rest were divided between Guadalupe and San Anselmo creeks. The Coyote sample contained both extremes and the three samples indicated that the average size at first scale appearance is the same in all three localities. It is safe to assume that local conditions have little or no effect, as otherwise there would certainly have been a marked difference between the Guadalupe and San Anselmo samples.

The age of fish at first appearance of scales is probably from two to three months. Scales appeared at three months in some laboratory specimens, but as these fish were reared under exceedingly artificial conditions, little can be deduced from this evidence. The first ripe fish in Coyote Creek were found on April 7; the first young fish with scales appeared in the same pool about June 20. Allowing 10 days for the incubation of the eggs, this would place the age of those fish at 2 months and 4 days. On June 20, young fish were found, the age of which could be placed within a few days of 3 weeks; whereas in the same place on August 12, specimens were found which would almost certainly not have had scales for another 2 or 3 weeks, thus indicating the other limit to be slightly over 3 months.

Although all the above evidence was taken from Coyote Creek, it is probable that it represents a fair approximation of the entire variation throughout the range of *Hesperoleucus*. Conditions vary widely in Coyote Creek and the two pools from which this material was taken represent exceedingly divergent conditions. One receives about ten hours of sun each day; consequently, it contains much algae and microscopic animal life. The other, being completely roofed over by trees, is exceedingly dark and contains little fish food. The more rapid development, of course, took place in the sunny pool.

First Circuli.

As the scales, when first formed, grow far more rapidly than the fish, there is a period when the circuli are quite widely spaced. The spaces, however, narrow down very rapidly as the growth rate of the scale slows down to about that of the fish. The number of circuli seems to be correlated with the size of fish rather than with age. Stunted specimens taken in February averaged less than one circulus more per scale than normal fish of the same size which were taken the preceding August (10 and 11 circuli for 23 mm. fish). Evidence from large samples of fish of the year taken during August and October shows that a dry fall may produce an almost complete cessation of growth, but rarely is any indication of this found upon the scale. A slight narrowing of the circuli is all that ever shows; three or four are crowded into the space of two or three.

During the latter part of the first year, the circuli continue to be evenly spaced until the check is reached, except in the case of those few fish which spawn at the end of one year. In the scales of such specimens, the spring growth of the first year resembles that of the following ones.

First Annulus.

The first annulus may be one of three types. The large fish (over 35 mm.) form a check which resembles the spawning mark formed in later years. There is an abrupt widening of circuli after the check; these outer ones are not concentric with the inner and are wavy, or even badly kinked. (See Fig. 28, F.) In smaller fish, this twisting of the outer circuli is usually lacking and the outer and inner rings are more nearly concentric; absolutely so in some cases. (See Fig. 28, D, and Fig. 29, A.) The third type of annulus is exceedingly rare in Coyote specimens but is present in the majority of those from San

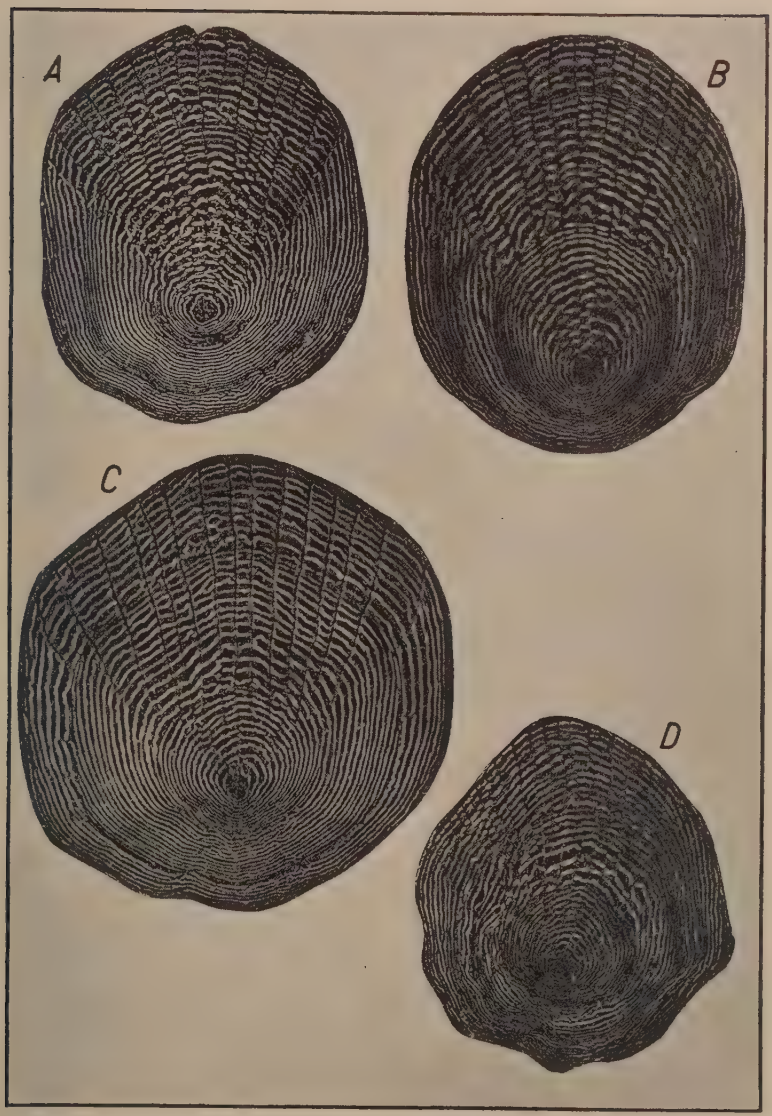

FIG. 29. Scales from *Hesperoleucus*.

A—Scale from 88 mm. female in third year. Coyote Creek, October 25.
B—Scale from 88 mm. male in fourth year. Coyote Creek, August 2.
C—Scale from 96 mm. male in third year. Coyote Creek, August 2.
D—Scale from 79 mm. male in sixth year. San Anselmo Creek, August 29.

Anselmo. The distinctive feature is that there is no marked difference in the width of the circuli inside and outside the check. There is, to be sure, a slight widening of the first two or three rings, but after this the width returns to about its former measurement. These fish, which are growing very slowly, do not mature at the end of their second year, consequently their second annulus resembles the first one of a normal Coyote specimen. (See Fig. 29, D.)

Time of Formation of Annulus.

The check seems to form, in general, about three or four weeks after the fish has spawned. The time is hard to determine accurately because the check can not be seen while it is in the process of formation. It can be distinctly seen six or seven weeks after the spawning has taken place and is probably about three weeks old at this time.

In fish which are too young to spawn, the annulus seems to form about two or three weeks earlier than in matured specimens. This time is even more difficult to determine than the above, as the immature fish usually have a far less distinct check and, indeed, often have none at all; a mere approximation of circuli taking its place.

Approximate time of formation of annulus for mature fish in different streams:

Guadalupe Creek ---------- May
Coyote Creek---------June, and possibly early July
San Anselmo Creek ---------- July
Russian River------July, and possibly early August

Russian River material was not collected by the writer and dates could not be verified.

Second Year.

The wide spacing of circuli after the first year is often marked enough to give the scale an appearance comparable to that of one from a salmon; the first year in *Hesperoleucus* being analogous to the period spent in fresh water by the salmon.

The spacing of circuli immediately after the first check is usually the widest in the life of the fish. It narrows down slightly and remains constant from late summer to early spring, except when there is a slight crowding in October or November due to a very dry fall. This crowding is even less conspicuous than that of the first year and is never more than barely perceptible. (See Fig. 29, C.)

In the spring there is a decided crowding of circuli which continues till the check is reached, after which the spacing immediately becomes far wider. This check is a "spawning mark", much the same as that found on the scales of Atlantic salmon, though far less distinctive. The mark on salmon scales is due to the resorption of the edge of the scale which results from the continuous tax on all tissues caused by the long migration, fasting period, and the ripening of the gonads. As *Hesperoleucus* has only the last of these difficulties to contend with, the strain is not nearly so great and there is very little, if any, eating away of scale material; consequently, the spawning mark, though distinct, is not nearly so glaringly apparent as that of the salmon.

Third and Following Years.

The circuli are wider, considerably, after the second check, but narrow down fairly steadily till the next one is reached. There is no long stretch of even spacing and consequently no trace of the effect of a hard summer is ever found beyond the second year. (For old fish, see Fig. 29.)

RELATIONSHIP OF SCALE GROWTH TO FISH GROWTH

After the discovery that the age of many fishes could be told by an examination of their scales, observers conceived the idea of extending the method slightly and using it to calculate the amount of growth from year to year.

The alternation of seasons, as previously explained, results in periods of rapid and slow growth and this, being reflected in the scale, produces the alternate bands which make age determination possible. As the width of these bands was found to vary from year to year, observers reasoned that this might be a reflection of the variation in annual growth of the fish.

The earliest assumption was that a fish and its scales grow proportionally at the same rate throughout life. This can be expressed in a formula:

$$L' = \frac{L \times S'}{S}$$

in which L = length of fish, S = length of scale, and L′ = length of fish at some previous date when scale length was S′.

This method makes possible a more or less accurate calculation of the length of a fish at any previous time in its life. The main difficulty is that, although this formula gives fairly satisfactory results when used to compute the growth during the more advanced years of a fish's life, the calculated results are far too low in the case of young fish. The reason is that scales do not form until the fish is of some size. This discrepancy led Fraser (1916) to introduce a constant into the scale equation, correcting for the length of the fish at time of formation of the scales:

$$L = C + \frac{S'}{S}(L - C)$$

C being the length of the fish at the time of first scale appearance.

This latter formula was developed for use on salmon and seems to work quite well on that fish. In consequence, it has come into fairly general use. It is, however, a straight line equation, which means that it is based on the assumption that once the scale is formed it grows at a rate which is constantly proportional to that of the fish. This is not strictly true in the case of any species which has been examined. In all cases, scales are formed as minute discs which have more or less space between them. These discs grow very much more rapidly than the fish until after they begin to overlap each other. If this early period just after formation of the scale is disregarded, a straight line equation will sometimes prove accurate.

The only exact method by which length calculations can be made from scales is to determine empirically the size of the scales on each size of fish. Such data can be most conveniently handled in the form of a graph.

To use such a curve, lay off the length of the fish on the base line, erect a perpendicular at this point, and measure off the scale diameter on that perpendicular. If the scale chosen is of such a size as to place the point thus obtained exactly on the empirical curve, the length of the fish at the time of formation of each annulus can be read directly. The graph is, of course, a representation of the average and as there is a considerable variation in scale size, getting one which will fall exactly on the line is a difficult task. The method, therefore, should be expanded to take care of a fairly wide range of sizes.

Huntsman (1918.1) developed a method of doing this by cutting his curve out of cardboard, pivoting it at a point experimentally found to be the most accurate, and rotating it so as to make the line hit any desired point. His description of the method of operation reads:

"A scale is taken from a fish of length L and the distance from focus to the limits of successive zones measured, the final one being from the focus to the anterior tip of the scale. These are denoted X_1, X_2, X_3, X_4, ... X.

"The curve is then adjusted until it intersects X vertically above L. The values of L_1, L_2, etc., corresponding to X_1, X_2, etc., can then be read off."

Huntsman makes the claim that scales can be taken from any part of the body and that this method will produce results accurate to within one-half centimeter. His data are rather sparse upon which to base this estimate, though he undoubtedly could attain at least that accuracy by using scales from a fairly limited area.

This system is exceedingly rapid, but is not mathematically accurate. A straight line is the only curve which can be thus rotated and still give exact results. (Huntsman's curve was fairly straight.) For instance, if a curve is convex upwards, as are most scale growth curves, and is pivoted at the base line, it can always be rotated far enough so that its highest point is in the middle. This, which would indicate that scales grow to a maximum and then shrink again, leads to an obvious absurdity.

Creaser (1926), working on the sunfish (*Eupomotis gibbosus*), uses Fraser's formula and a table of corrections. This can undoubtedly be made to give accurate results, but is rather cumbersome.

A theoretically exact way to accomplish the same purpose is to multiply the scale diameter by whatever factor is necessary to make it fall upon the curve. Then by multiplying every other measurement made upon that scale by the same factor, accurate results can be attained. This system is quite slow if carried out as explained, but it can be converted into a very rapid process quite easily.

A system of doing this mechanically is to use a microscope with a micrometer eyepiece to measure the scales. The mean curve is then plotted in micrometer units of scale diameter against fish length in inches or centimeters. By sliding the draw tube of the microscope in or out, the magnification can be changed so that the scale measures the exact number of micrometer units necessary to fall upon the

curve. The other measurements are then made at this same magnification and the fish lengths read directly from the graph. Another way of producing the same effect is to project an image of the scale on a screen. By changing the distance between the screen and the projection apparatus, the magnification can be adjusted until the image has the desired diameter.

Scales Used in Construction of Graph.

Scales for use in the construction of a curve of the type discussed may be from almost any part of the body, provided, of course, the same ones are taken from each fish. Some workers prefer to use a single scale, for instance, one of peculiar shape which they can locate exactly; others take an average of several from a more or less restricted area of the body.

The writer selected scales from the side, two or three rows above the lateral line and in or near the row extending downward and forward from the front edge of the dorsal fin. This region was chosen because it contains scales which are among the largest and most easily read of any on the body, as well as being those first formed in the larval fish.

A small group of these scales was measured and the diameter of the largest one recorded. The reason for using one measurement instead of an average is that the writer wished to obtain data from the smallest fish, since very little work has been done on the extreme lower end of these curves. The newly formed scales start growing exceedingly rapidly as soon as they appear. This means that for some time the first scales formed will be by far the largest. By taking one of these, the graph can be carried back to the first appearance of scales and will still give an accurate picture of the relative growth of scale and fish. If, on the other hand, an average is taken, the more newly formed scales will keep the average down and distort the curve until the growth rate of all the scales has slowed down to approximately that of the fish. As the method proved entirely satisfactory for large specimens as well as small ones, there was no reason to change it, especially as to do so would put a break in the graph.

Even for adult fish, there are some decided disadvantages in taking an average of scale measurements. Regenerated scales, which are smaller than normal ones and therefore can not be used, are often present in such numbers that it is impossible to get enough unregenerated material from which to take an average without descaling a large enough area to bring in some error due to the variation in scale sizes in different parts of the body.

The largest scales are fairly uniform in size, *i.e.*, there are none which are markedly larger than average. There are, however, quite a few which are far smaller. The presence or absence of one or two of these in a sample of ten will make a noticeable difference in the mean.

For these reasons, the writer decided that measurement of the largest scale would prove more satisfactory than taking an average.

To check this assumption, two portions of the curve were plotted with averages, ten scales being used for the location of each point. The two methods were then compared. The portion of the curve ranging from 25 to 35 mm. had a dispersion of points averaging 6 per cent

from the mean in the case of the "average" graph, as compared with 2.1 per cent when the largest scale was used. In the case of larger fish (70–80 mm.) the two dispersions were equal (2.5 per cent).

Choice of Scale Measurements.

In the discussion of scale shapes it was pointed out that different parts of a scale grow at different rates, and that these rates change with respect to each other at different sizes and ages. It is obvious, then, that the same field of the scale must be used for all measurements.

The different parts of the scale have all been used in work of this type. The field found most satisfactory for use on one species in some cases can not be used on another. For example, in research on the herring, the longitudinal diameter has been much used. In the salmon, however, circuli do not extend clear around the scale. The exposed portion is smooth and shows no trace of any markings. Obviously in this case, measurements must be made in such a way as to exclude this unmarked posterior field. As a rule the anterior radius of a salmon scale is used.

Creaser (1926), working on sunfish, made separate curves, using the anterior radius, posterior radius, and total scale length. He found the anterior radius to be most satisfactory.

Lea (1910), in his investigation of the herring, did some work with a special scale from the opercle. He used its dorso-ventral diameter and obtained quite satisfactory results.

In working upon *Hesperoleucus,* the writer used measurements of both length and width (dorso-ventral diameter) of the scales and obtained strikingly different results in the two cases.

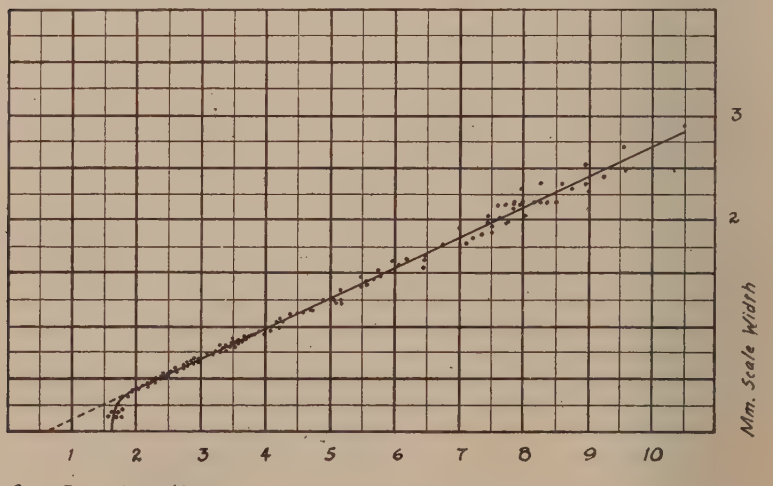

FIG. 30. Scale width plotted against body length.

The scale width-body length curve (Fig. 30), being far simpler, will be described first. This curve is for most of its length a straight line and consequently can be fitted by Fraser's formula. Fraser used the length of the fish at time of first scale formation as his constant.

This, which would be 16.7 mm., is far too high a value in the case of *Hesperoleucus*. Six mm. was found to be correct.

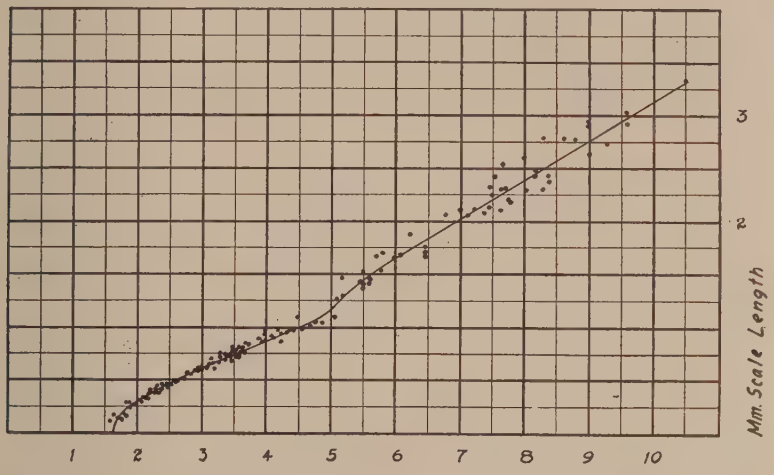

FIG. 31. Scale length plotted against body length.

The formula, in the case of *Hesperoleucus*, would then read:

$$L = 6 \text{ mm.} + \frac{W'}{W} (L - 6 \text{ mm.})$$

W and W′ being scale widths.

The empirical curve leaves the base line at 16.7 mm., rises very abruptly, bends, and joins the curve of the above equation at 19 or 20 mm., after which the two are identical.

At first, the scale length graph falls somewhat below the other curve. This difference is about 0.09 mm. by the time the fish has attained a body length of 22 mm. (The scale at this time measures about 0.36 x 0.45 mm.) From this point until a body length of 45 mm. has been reached, the curves continue to diverge but much more slowly. The distance between them increases from 0.09 to 0.13 mm. At about 45 mm. the length curve bends upward and then continues in its new direction as a straight line which crosses the other graph at about 50–55 mm., body length. (See Figs. 31 and 32.)

A fair idea of the relative accuracy of the two curves here described can be had by glancing at the dispersion of points in each case. Mathematically expressed, the deviations from the mean in the two curves are as follows:

Curve using	Mean deviation	Maximum deviation found	Probable limit 3σ
Length of scale	4.0%	12%	17.8%
Width of scale	2.5%	8%	11.1%

Because of its greater accuracy, the second of these two curves (width) was used for growth rate work. As this graph is a straight line for all fish above 20 mm., the method of Huntsman can be used with accuracy. If this is done, the pivot should be placed on the base line at the 6 mm. mark.

The writer used Huntsman's method as well as the one of his own which operates by adjusting the draw tube of the microscope. There was little to choose in the matter of ease and rapidity of operation.

Possible Sources of Error.

Scales and fish may grow at relatively different rates at different times of year. With this in mind, the fish to be used for the construction of the curves in question were taken at all times of the year, including just before and after the formation of the annulus. No differences could be detected between these groups.

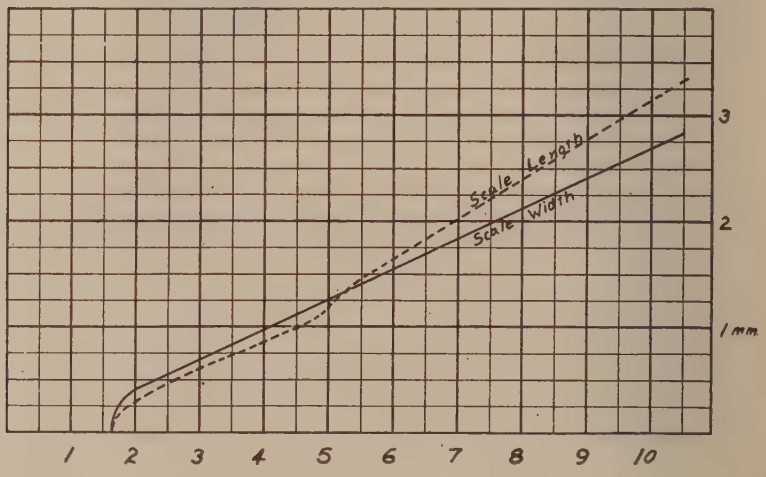

FIG. 32. Scale width and scale length plotted against body length.

Fish of the same size but of different ages may have different sized scales. By using some undersized specimens from San Anselmo and some extra large ones from Coyote, it was proved that this is decidedly not the case when the width of the scale is the measurement taken. When scale length is used, this factor does enter into play to a slight extent. The upward bend in the curve comes at a smaller size in the case of slowly growing fish. Scales of different sizes may not be growing at proportionately the same rate. This was checked by taking ten scales from a fish and using each of these to calculate its length at the time of formation of every annulus. The process was repeated with several individuals. Results from a 72 mm. San Anselmo specimen in its fifth year follow:

Calculated Length in mm. at Time of Formation of Each Annulus

	1st	2d	3d	4th
	23.2	35.5	49.0	58.0
	22.3	33.8	47.5	58.0
	24.5	35.5	47.5	58.0
	24.5	36.3	46.7	58.0
	23.2	36.3	47.5	58.0
	23.2	33.8	46.0	57.5
	23.8	35.5	48.3	58.0
	23.2	34.6	49.0	58.0
	23.2	35.5	48.3	58.5
	23.2	35.5	46.7	58.0
Mean	23.43	35.23	47.65	58.00
Maximum deviation from mean	1.13	1.43	1.65	0.50

In general, the older fish give the greatest errors by this method. A specimen in its sixth year (the oldest seen by the writer) gave a maximum variation of 1.85 mm. from the mean, whereas a three-year-old, though 17 mm. longer, gave all readings within 0.6 mm. of the mean.

The uniformity of these results disappears as soon as scales are taken from different parts of the body. The following table compares lengths calculated by using lateral scales and by using ventral scales.

Calculated Length in mm. at Time of Formation of Each Annulus

	1st	2d	3d	4th
Lateral scales	23.4	35.2	47.6	58.0
Ventral scales	29.0	39.5	53.0	61.5

This shows very conclusively that scales to be used for making calculations must be taken from a fairly restricted area.

RATE OF GROWTH

In the streams inhabited by *Hesperoleucus,* the time of year at which certain physical changes take place varies over a period of about two months. As biological conditions are correlated with physical ones rather than with time of year, the seasons of *Hesperoleucus* show about the same variation. In some places the larvae appear as early as the first of April; in others as late as the beginning of June.

When the larval *Hesperoleucus* first absorb the yolk sacs and begin to look for food, they find conditions which are ideal for their development. The water has stopped flowing to any extent, except in the deeper channels, but is still high enough to cover the more level parts of many gravel bars. This results in large areas of very shallow, still water. These places are safe from all kinds of larger fish and also contain an ample food supply.

As the water continues dropping, it becomes confined to the steeper-sided channels and pools. The flat-topped bars are left dry and the fish are crowded into much more restricted areas. In one small cove, perhaps three feet across, over 2000 young minnows (mostly *Hesperoleucus* and *Orthodon*) were taken by the writer with one clip

of a small butterfly net (Lower Coyote Creek, near Alviso, June 5, 1927).

Fish so tightly packed together are naturally easy prey for any animals on the shore, but those which venture into deep water are in far greater danger from other fish. In this respect, the oldest fish, being of edible size for a smaller number of enemies, have a comparative advantage.

FOOD CONDITIONS

In creeks such as San Anselmo, Lower Coyote, and the Russian River, where there is flowing water throughout all or nearly all of the summer, food conditions are much the same in different parts of the stream. The current carries many minute organisms with it and insures fairly even distribution. Even if some area should have a food shortage, there would be nothing to keep its inhabitants from leaving it in search of a better feeding ground. As a result of such conditions, fish from one part of the stream grow at about the same rate as those from any other part.

Most of the streams inhabited by *Hesperoleucus,* however, dry up except for the larger pools and some narrow strips of water where the current has cut under a root-grown bank. There is a great deal of difference in the amount of food found in these two types of places. The water under the banks is shaded and cold; consequently, aquatic insects and small organisms of all kinds are scarce and almost the entire food supply must fall off the bank and trees. The large, open pools, on the other hand, receive much sunlight and are usually well supplied with pond scum, which is invariably teeming with microscopic organisms which form an abundant food supply. The fish in such places grow much faster than those living in shaded water.

On August 2, 1927, young *Hesperoleucus* from a large, sunny pool averaged 30.2 mm., body length, whereas 10 days later those from under a shaded bank half a mile away had a mean length of 24.5 mm., a difference of 5.7 mm. In other words, those from the pool had grown over 23 per cent faster. All of them were fish of that year's hatching.

The early summer advantages of a warm, open pool last throughout the year if the pool remains large enough to prevent excessive crowding during the dry season. Many creeks, however, are prone to dry up entirely, or nearly so. Complete drying out, of course, removes the fish from all danger of being used as material for a growth curve; but when any water at all remains throughout the year, a few *Hesperoleucus* are nearly always able to exist. When a large pool shrinks to a pocket containing about a half barrel of warm, dirty water, the fish in that pool naturally do not grow appreciably until the winter rains provide water and food.

Guadalupe Creek has many long, dry stretches, a few places where the water gets very low, and still fewer large, deep holes. As a result, this stream produces many stunted specimens of *Hesperoleucus,* as well as some of the largest that it is possible to obtain. A sample of 30 Guadalupe *Hesperoleucus,* which were just beginning their third year, ranged from 48 to 96 mm., body length, and fell into two fairly distinct size groups. One ranged from 48 to 68 mm. and had a mean of

59 mm. The other was from 73 to 96, with a mean of 89 mm. An examination of scales showed that almost all of the difference was in the second year's growth.

This same sort of comparison can be made between different creeks. In doing this, young fish were not used because the difference in hatching time in the various localities can not be accurately allowed for.

The following figures are for fish just beginning their third year, except in the case of those from San Anselmo Creek, which were about three months older.

	Minimum	Maximum	Mean
Guadalupe Creek	48	96	71
Coyote (Upper) Creek	40	85	65
San Anselmo Creek	40	68	53

LARVAL GROWTH RATE

When the young *Hesperoleucus* is hatched, it has a body length of about 5 mm. During the first three days, it lengthens to about 6½ mm., and by the end of a week has reached 7 mm. This was found to be the case both in laboratory specimens and in individuals living under natural conditions in a partly isolated portion of a pool in Guadalupe Creek. At the age of a week the fish began swimming about and it was no longer possible to be certain of the exact age of the wild specimens, as they might have mingled with others of a slightly different age. The variation in size up to this time was about 0.8 mm., *i.e.*, about 0.4 mm. from the mean.

At the end of two weeks the laboratory specimens were about 8 mm. in body length. Increase in length from this point on was even slower than before, but the fish were broadening out and attaining a more mature appearance. At an age of 9 to 10 weeks the length was about 10 mm., after which the fish began to grow far more rapidly. At 12 weeks they measured 12 mm., at 13 weeks they had reached a length of 16½ mm. and had completed their larval growth.

As has been previously mentioned, the size of stream fish at completion of larval growth is 16.7 mm. (± 1 mm.) and the age is from 8 to 14 weeks.

POST LARVAL GROWTH

Due to the widely divergent conditions in Coyote Creek, it was decided that in order to obtain a certain degree of uniformity, only fish taken from the more open and sunny portions of the stream would be used. The apparent alternative of confining observations to the inhabitants of some one large hole was found not to be feasible, as almost all of the fish which congregated in such places during the dry season were found to leave as soon as high water permitted them to do so. As a result, there was bound to be a certain proportion of fish from more shaded portions of the stream. This habit would tend to reduce the uniformity of samples taken.

The spot chosen by the writer as a winter fishing ground was situated below an open, sunny stretch of over a mile in length, and above a series of exceedingly swift rapids up which it seemed probable that few if any small minnows would swim. The fact that among the

specimens taken there is no drop in the rate of increase of average size after the first rains may be taken as an indication that no large numbers of fish from deeply shaded areas had migrated into the fishing ground.

A sample of 50 fish of the year was taken on July 11. The ages of these fish, as estimated from the spawning time of the adults, would be between 6 and 13 weeks. Their size varied from 10 to 32 mm., with a mean of 19.3 mm.

One hundred individuals taken on August 2 indicated that growth during this period of the year is exceedingly rapid. In this case the extremes in size were 21 and 41 mm., the mean 30.2 mm. The two samples were taken from different but equally sunny pools.

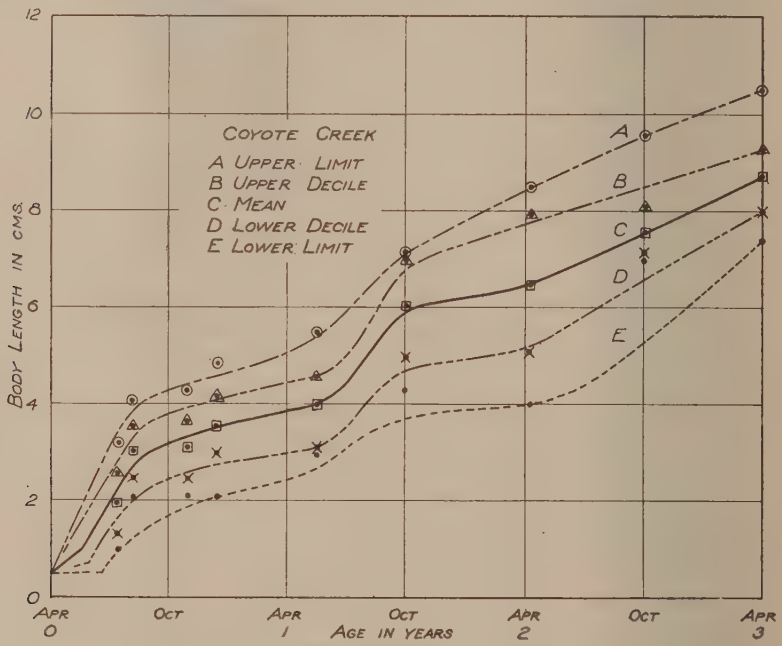

FIG. 33. Growth rate of *Hesperoleucus venustus* in sunny sections of upper Coyote Creek.

By August the creek had dried up to such an extent that it became excessively crowded, and by October the water had cooled sufficiently to kill all the *Spirogyra*, thus removing the basis of food supply. This would seem to account for the fact that from August to November the rate of growth appeared to be exceedingly slow. A sample of 100 fish taken on October 25 averaged only 1.1 mm. longer than those taken from the same pool on August 2.

By December 9, the stream had risen and all fish were taken outside of the deep holes. The 280 fish taken at this time averaged 36.3 mm.

Growth through the winter and spring appeared to be at a rate slightly under 1 mm. per month. Examination of scales would lead an observer to believe that in many cases there is complete cessation of growth about May. The average length on May 13 was 39.8 mm.

Second-year and older fish proved difficult to obtain, consequently it was found necessary to combine catches made over a period of several weeks and average the dates of capture. This makes it impossible to obtain more than a general idea of their seasonal growth rate.

From May to October of the second year, growth was very rapid. The average size increased 20.9 mm. (39.8 to 60.7 mm.), while during the next six months (October to April) only 4.3 mm. were added, indicating a slowness of growth similar to that observed during the winter and spring of first-year fish.

Among second-year and older fish, the check in the scales formed during the spawning period would indicate that all individuals experience a period of growth cessation at this time (April and May in Coyote Creek).

Among third-year fish, no trace of seasonal variation was found. The increase from April to October was 10.5 mm., whereas for the following period of six months it was 11.8 mm., instead of less than half that amount as previous data would have led one to expect.

As only two fish more than three years old were taken in Coyote Creek, no attempt was made to carry the work beyond this point.

Table of Growth, Coyote Creek Fish, in mm., Body Length

	Lower limit	Lower decile	Mean	Upper decile	Upper limit	Number of specimens
1st year:						
July 11	10	13	19.3	26	32	50
Aug. 2	21	25	30.2	36	41	100
Oct. 25	21	24.5	31.3	37	43	100
Dec. 9	21	29.8	36.3	42.1	48	280
May 13	29	31.5	39.8	46	55	50
2d year:						
Oct.	43	50	60.7	70	72	20
April	40	51	65.0	79	85	25
3d year:						
Oct.	70	71.5	75.5	81	96	40
April	74	80	87.3	93	105	14

RELATIVE SIZES OF MALES AND FEMALES

The females of this species are on an average slightly larger than the males. The difference appears to be about 6 per cent for adult fish.

	Sizes, mm., body length		Number in sample	
	Males	Females	Males	Females
1st year	31.0	32.5	30	30
2d year	53.8	56.5	31	7
3d year	71.8	77.0	20	20

GROWTH AND MORTALITY

Among *Hesperoleucus* the individuals which grow the most rapidly are, in general, the shortest lived. This is most easily seen by comparing the length of life of fish from different streams.

Very rapidly growing individuals are found in Gaudalupe Creek. An examination of the scales of 50 adults from this stream disclosed that none was over three years old.

Specimens from Coyote Creek grow quite rapidly and an examination of the scales of 150 adults disclosed two which were in their fourth year, the remainder being three years or under.

San Anselmo Creek, by way of contrast, is a stream in which growth is exceedingly slow. A sample of 25 individuals over 40 mm. in length was found to contain 7 fourth-year specimens, 3 in their fifth year, and 1 in the sixth year.

The maxium size of the fish from San Anselmo, is, in spite of their greater age, much less than that of individuals from either of the other two streams. Three-year fish from Coyote and Guadalupe creeks *averaged* 87 and 93 mm., respectively. The *largest* fish taken from San Anselmo was a fifth-year specimen which measured 80 mm.

Ten per cent of the largest individuals found in Coyote Creek measured from 46 to 55 mm. This statement is based on a small sample of 50 fish taken May 13. A sample of 280 taken the preceding December showed the largest 10 per cent to be from 42 to 48 mm. If these had grown at the same rate as the mean, they would have ranged from 46 to 52 mm. by May. From this evidence it is safe to say that about 10 per cent of the young *Hesperoleucus* are over 46 mm. long by the end of their first year. This would mean that out of a sample of 150 adults, 15 would be expected to show scale measurements indicating that they had been 46 mm. or more in length at the end of their first year. Actually, however, instead of 15 only 3 were found. This would tend to indicate, as did the maximum ages in Coyote, Guadalupe, and San Anselmo creeks, that the more rapidly growing fish die at an earlier age.

AGE AT MATURITY

Fish from Coyote Creek matured, in general, at the end of the second year. Less than 10 per cent of the largest individuals spawn at the end of one year, and one fish was found which had not spawned until its third year.

Guadalupe Creek fish appear to resemble those from Coyote Creek in this respect. Those from San Anselmo Creek, on the other hand, do not mature in most cases until the end of their third year.

SIZE AT MATURITY

The smallest spawning male found in Coyote Creek by the writer measured 46 mm. The smallest from Guadalupe was 0.5 mm. longer. Spawning females as small as 50 mm. were found in Coyote Creek.

SUMMARY

Larval food consists principally of diatoms, unicellular algae and crustaceans.

Small fish (under 40 mm.) are usually strictly carnivorous.

Larger individuals are carnivorous throughout most of the year, but eat *Spirogyra* exclusively when other food is scarce during the dry season.

The number of ripe eggs ranged from 250–900 in the individuals examined.

The spawning season lasts about two months in any one stream.

The beginning of the spawning season varies from about March 15 to about May 1, depending on the amount of sunlight received by the stream.

Spawning takes place without any migration, in a small area in or near the home pool.

The fish deposit their eggs in cracks between rocks submerged in flowing water less than 4 inches deep.

The incubation period is about 10 days.

Larvae, for about a week after they hatch, hide in gravel.

Feeding, in laboratory specimens, commenced at 10 to 14 days.

Larval period, until the formation of scales, is about 8 to 14 weeks.

Scales and pharyngeal teeth appear when fish are about 16.7 mm. ($\pm$ 1 mm.).

Appearance of certain organs in the larvae is regulated by size rather than by age.

Shape of scales varies greatly on different parts of the body and to a lesser extent with the age of the fish.

Size of scales varies in different parts of the body.

Life history can best be interpreted, in the case of *Hesperoleucus*, from the lateral fields of the scale.

Scales appear at 16.7 mm. ($\pm$ 1 mm.), regardless of age. The age of appearance seems to be from 2 to 3 months.

Circuli vary in number with size rather than with age of fish.

There may or may not be a slight crowding of circuli during the first two dry seasons. After that, there is none.

The first annulus (first two, in San Anselmo Creek) is generally less distinct than the following ones, and is followed by a much wider spacing of circuli.

The annulus in adult fish is formed 3 or 4 weeks after the fish has spawned. Immature fish seem to form an annulus on an average of 2 or 3 weeks earlier than the adults.

Growth rate may be calculated with accuracy from scales, but only when empirical data have been obtained on relative growth rates of scale and fish for the species being examined.

Different fields of the scale do not grow at proportionately the same rate.

The dorso-ventral diameter of the scale is the most satisfactory measurement to use in the case of scales from *Hesperoleucus*.

Scales used for calculations need not be of the same size, but must be from the same part of the body. Adjustment for different sizes of scales can easily be made by varying the magnification until the image measures the desired diameter.

Accuracy to within 2 mm. can be depended on in any specimen of *Hesperoleucus*, and an accuracy of 1 mm. in specimens under 3 years of age.

Growth is far more rapid when there is an abundance of sunlight, provided there is sufficient water to prevent crowding.

Growth is rapid through the summer, decreases when dryness causes crowding in the fall, and is rather slow throughout winter and spring.

Females average about 6 per cent larger than males.

More rapidly growing fish appear, in general, to die at an earlier age than others.

Normal age at maturity is two years in Coyote and Guadalupe creeks, and three years in San Anselmo Creek.

Minimum size at maturity is about 46 mm. in males and 50 mm. in females.

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THE WADDELL CREEK EXPERIMENTAL STATION FOR TROUT AND SALMON STUDIES

By A. C. Taft, Assistant Aquatic Biologist, U. S. Bureau of Fisheries

The California Trout Investigations, working under a cooperative agreement between the United States Bureau of Fisheries, the California Division of Fish and Game, and Stanford University have been carrying on a study of the steelhead trout since the fall of 1931. These studies have been directed towards obtaining such facts regarding the life history and habits of the steelhead as would assist in their conservation and fullest utilization.

It early became apparent that what was most vitally needed was more exact quantitative data as contrasted with the observational character of the material which had been obtained in previous years.

The most important facts in the life history of the steelhead center in their migrations, first as young fish from the streams to the ocean, and, second, as adults when they return to the streams to spawn. These migratory movements are directly important as an outstanding feature in the life of the steelhead and indirectly for the opportunities for conservation which they make possible.

In order to gain the fullest knowledge regarding these migratory movements a trap was desired which when installed in some small stream would take all of the adult fish entering from the ocean and a sufficient portion of the small fish moving in the opposite direction to give a satisfactory sample at all seasons of the year.

Due to the nature of the coastal streams there is considerable difficulty involved in designing a trap which will meet the above specifications. These streams carry only a small amount of water during the summer months but during the winter and spring, when most of the migrations occur, they increase tremendously in volume and carry a large amount of debris from the forested hills which they drain.

Scott and Waddell Creeks in the northern part of Santa Cruz County were selected for experimental work. The former has been used as a source for steelhead eggs for over twenty years and a state hatchery was built on one of its tributaries in 1926. Two miles from the mouth of Scott Creek is the egg taking station which consists of a dam that is impassable to fish moving upstream and a fish ladder which leads into a trap and thence to holding tanks where the fish are kept until ready for spawning.

During the summer of 1933 a similar dam and trap were constructed on Waddell Creek* with the addition of facilities for taking a portion of the small fish moving downstream at all seasons of the year. This trap has now been in continuous operation for two years and has been sufficiently successful to warrant its description in considerable detail.

* The Waddell Creek Station is available through the kindly interest of Dean T. J. Hoover, who provides residence and laboratory facilities on the grounds.

Figure 34 is a photograph of the station in operation during high water. To the left is the dam, the apron covered with water, and the swinging galvanized sheets which prevent the passage of fish. On the right is the tank which forms the trap proper and between it and the apron is the flume which brings water from above the dam, and below it is the entrance to the fish ladder leading to the upper end of the trap.

FIG. 34. The Waddell trap during high water.

Excess water from the flume can be seen spilling through the screened by-pass just before the flume enters the lower end of the tank.

The construction and method of operation of the trap can be more readily understood by reference to Figure 35 which is a ground plan of the trap, flume, fish ladder and a portion of the dam. The arrows indicate the course of the water flow and the gates which are used for control of the water have been numbered from I to VI, inclusive.

The water enters the flume from above the dam through gate I which is a 12 by 36 inch opening in the protecting wall. This opening is set below the level of the dam so that its upper edge is just level with the crest of the dam. This was done to insure a flow of water into the flume at all stages. To further insure this the crest of the dam was given a slope of 4 inches from the opposite bank towards the trap. The flow of water through gate I is controlled by a gate which slides in slanting grooves. This gate is put in place from the outside but during high water can be raised and lowered from inside the flume by the use of a pinch bar. The water passes down the flume to gate II which is a spillway that makes it possible to control the water flowing into the tank at gate III without changing the adjustment of gate I. It also makes it possible to handle water in excess of that which can be cared for by the screens in the tank. This gate was originally covered by a stationary screen that has recently been replaced by a moving

screen of spiral weave conveyor belt. The remaining water passes through gate III and drops into the tank where the water is carried at a depth of between 3 and 3½ feet.

The water passes through the tank in an upstream direction and is strained through two sets of screens. The first screen is of half inch mesh and the second of quarter inch mesh. Both are made in two sections of 3 by 6 feet to make them easier to handle. All fish coming into the flume from upstream are thus trapped below these screens. The use of the two sizes of mesh makes it easier to keep the screens clear of debris and also segregates the small fish from the large, including the cottoids.

The water then passes through outlet IV into the upper step of the fish ladder and then down through the two remaining steps and back into the stream. The adult fish come to the fish ladder through inability to pass the dam and ascending it pass through inlet IV into

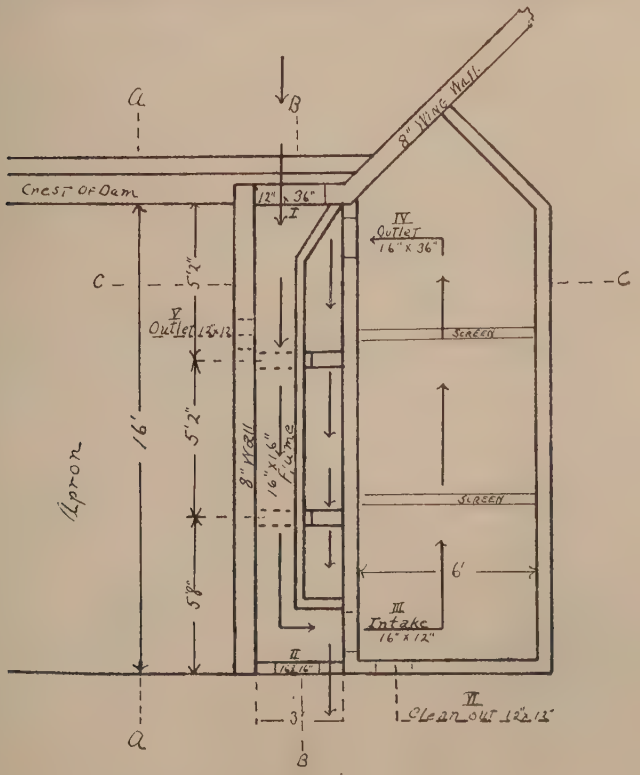


FIG. 35. Ground plan of the Waddell Creek trap.

the upper end of the trap. Their return into the fish ladder is barred by pivoted finger gates which nearly close the opening. The current holds these gates in a closed position but they move freely enough so that in following the current the fish can push them open to enter the tank. The steps in the ladder are only 14 inches high so that small fish moving upstream are also taken in the upper end of the trap.

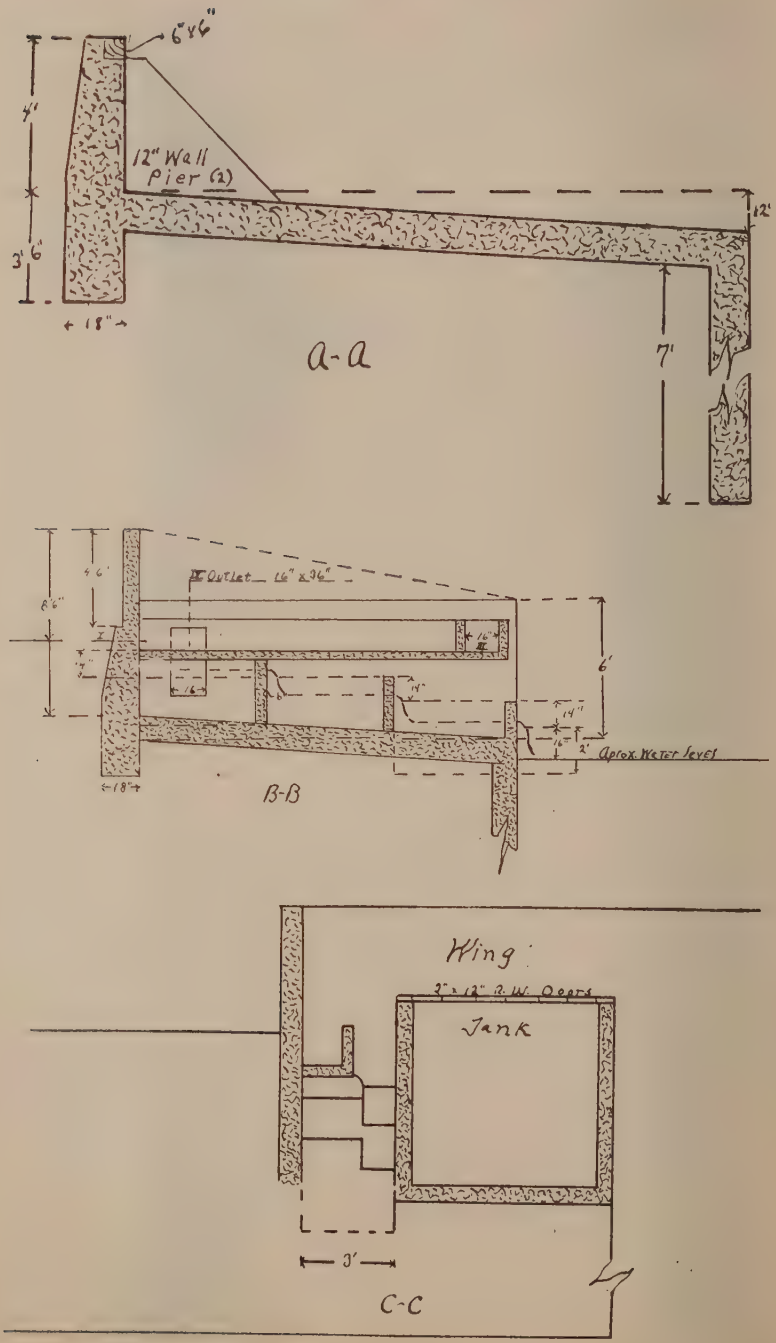


Fig. 36. Sectional plans of the Waddell Creek trap and dam.

Outlet V opens from the bottom of the upper step of the ladder cut on to the apron of the dam. This gate is used to lower the water level in the tank when it is desired to work with the fish which have been trapped. When it is opened the water, which has been held at the level of the port of the upper step in the ladder, falls to the level of the bottom of gate IV. It would probably be an improvement to have gate IV set from 8 to 12 inches lower than indicated in Figure 36 to aid in netting the fish. Flow of water through outlet V is controlled by a gate which is attached to the lower side of the opening by hinges and is held closed by water pressure. It is opened from the fish ladder by means of a hook as it would be impossible to get at it from the apron during high water. Gate VI is a clean-out at the bottom of the tank and is used only during low water to remove debris which has accumulated on the bottom of the trap.

In constructing the dam and the apron it was necessary to keep them as low as possible due to the fact that in the past the water has been known to rise to the level of the bank at the top of the steps shown at the right in Figure 34.

Every foot that the dam was raised increased the danger of causing flood waters to pass around the dam and wash it out. As a result the apron was lowered to low water level at its lower edge, which is approximately a foot below the level shown in Figure 36. During the first season of operation it was found that at flood stage, such as shown in Figure 34, the water piled up on the apron to such an extent that the adult fish were able to jump over the dam from the eddies back of the supporting piers. This was immediately remedied by the installation of the galvanized sheets which show in Figure 34. A $\frac{3}{8}$-inch cable was strung 5 feet above the crest of the dam and from it the 6-foot sheets were hung after being framed with 1 by 2-inch redwood strips for stiffening.

This arrangement has worked very well in preventing the fish from jumping the dam and at the same time allowing water and debris to pass without hindrance. Large logs and trees have passed through without serious damage to the sheets. The fish are unable to jump through the opening between the bottom of the sheets and the crest of the dam due to the fact that the water is very swift and turbulent where it strikes the apron and prevents their getting a start for the almost vertical jump which would be necessary.

Our seasonal catch covers the period October 1 of one year to September 30 of the following and we now have complete figures for the 1933–34 and the 1934–35 seasons. Table 1 shows the number of fish so far taken in the trap. A miscellany of sticklebacks, frogs, salamanders and snakes swimming downstream into the trap has not been included.

TABLE 1. FISH TAKEN IN THE WADDELL TRAP

	1933–34	*1934–35*
Silver Salmon, adults upstream	498	595
Steelhead, adults upstream	433	544
Silver Salmon, migrants downstream	3,430	3,567
Steelhead, migrants downstream	3,117	1,795
Cottoids, downstream	3,357	1,830
Totals	10,835	8,331

It is obvious that one of the major objectives that might be attained through the operation of the trap is an enumeration of the spawning fish and their resulting progeny when they return as adults from the ocean. Since the life of the steelhead before maturity is divided *by their migration* into the two major periods of stream and ocean life it would be desirable also to have a count of the number of young fish migrating to the ocean each year in order to segregate the mortalities occurring in the two parts of the life cycle. Only a portion of the water flowing in the stream can be passed through the screens of the trap during high water and therefore only a portion of the fish passing downstream can be taken. In order to determine the total number of young migrants most of these trout and salmon taken in the trap are marked by the removal of fins. The total number of migrants is then determined through the ratio of marked to unmarked among the adult fish when they return and are taken on their upstream migration. This ratio can only be used after the fish have been aged through a reading of their scales.

During the coming season of 1935–36 sufficient additional returns should be received from the marking of migrants during 1933–34 to make possible the determination of the total number of migrants during that season. It will thus be possible to calculate the percentage of the total number of migrants taken by the trap and this will be reported upon at an early date.

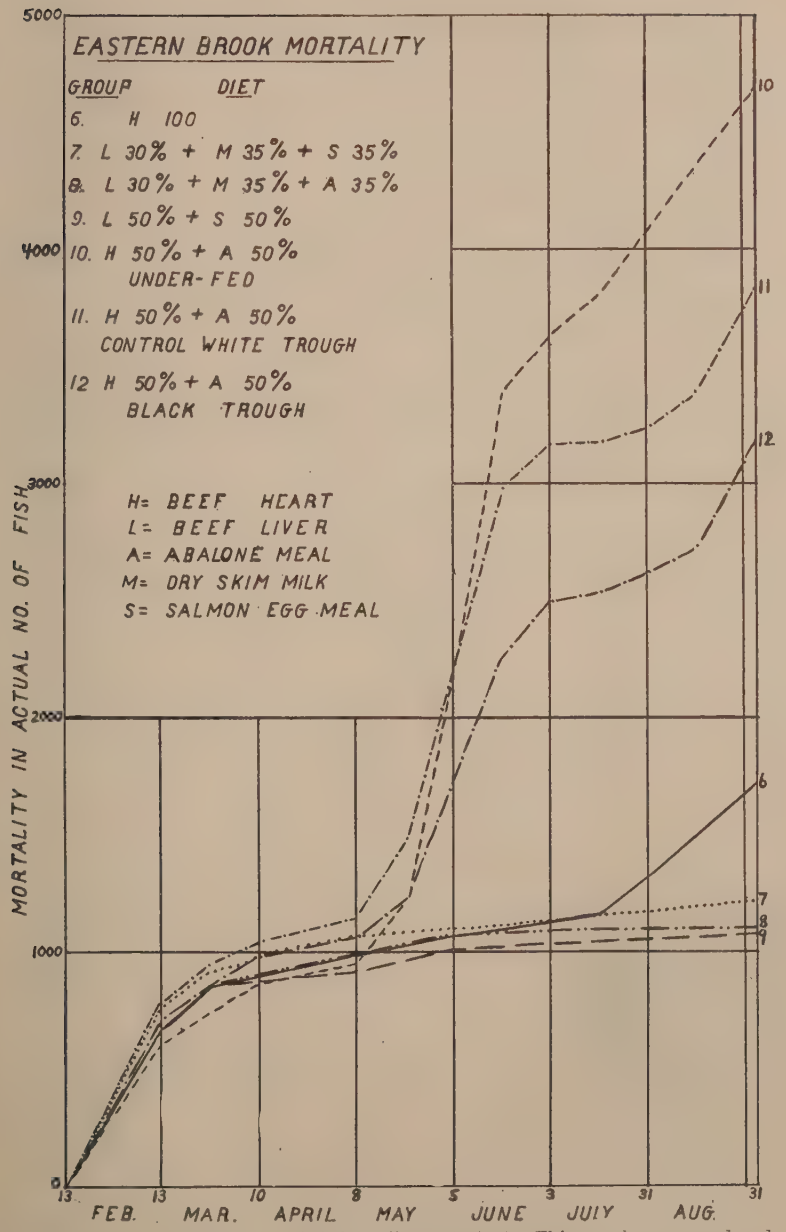


FIG. 37. Each group had 46,000 fingerlings at start. This number was reduced to 30,000 on May 29. On June 26, 10,000 fish were removed from groups 6, 7, 8, 9. On July 24, 10,000 fish were removed from groups 7, 8, 9.

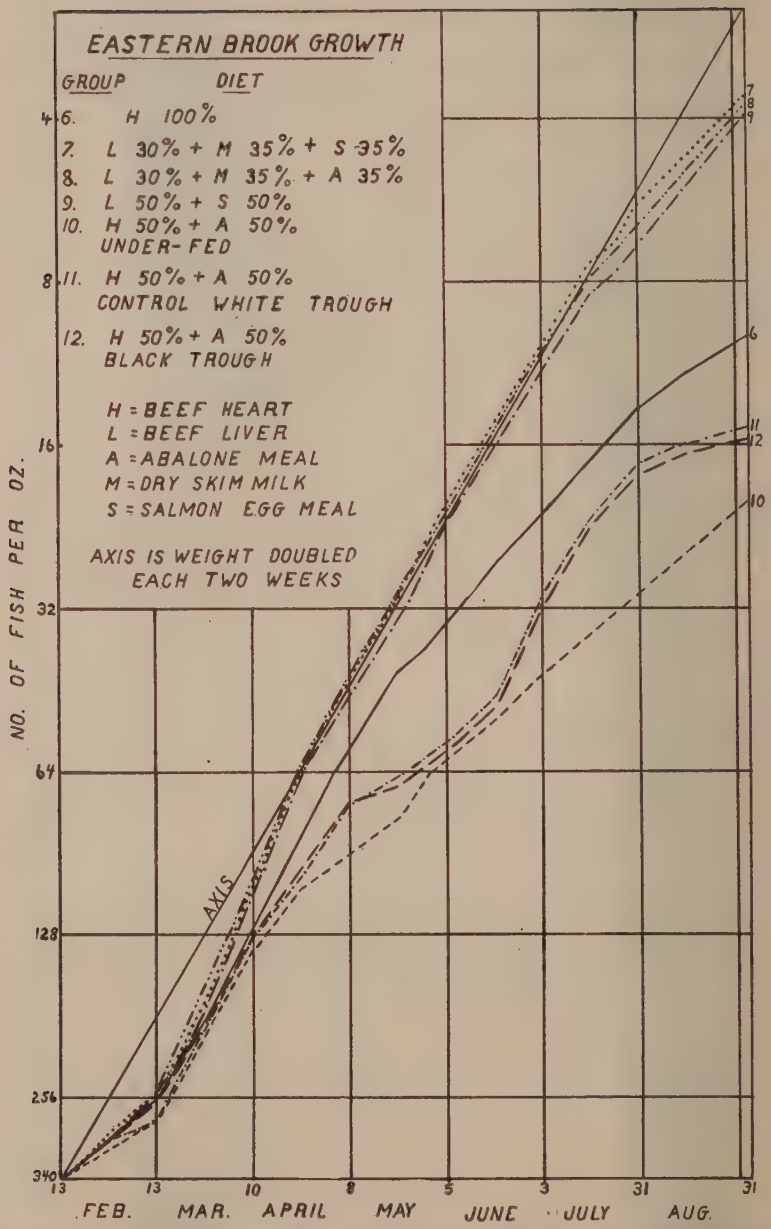


FIG. 38. Growth curve comparing the Eastern Brook diets with an "axis" which represents a doubling of weight each two weeks. Each group had 46,000 fingerlings at start. This number was reduced to 30,000 on May 29. On June 26, 10,000 fish were removed from groups 6, 7, 8, 9. On July 24, 10,000 fish were removed from groups 7, 8, 9.

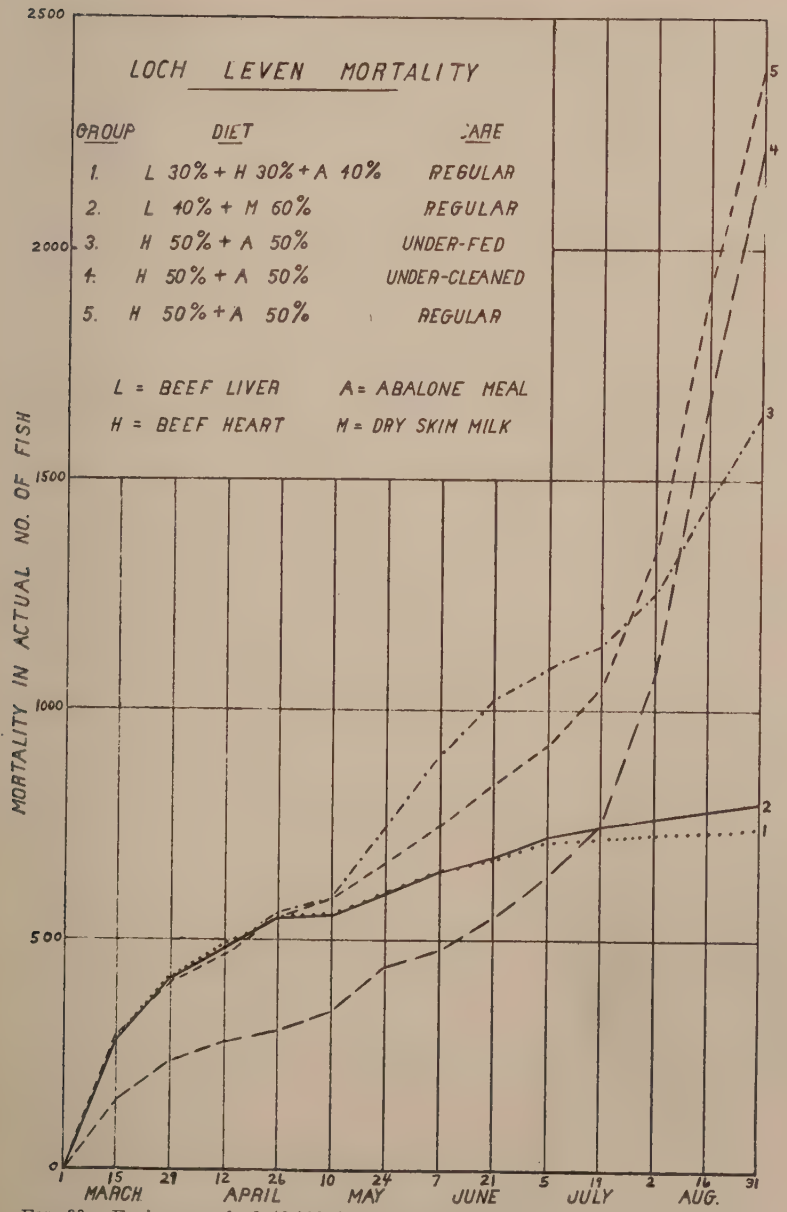


FIG. 39. Each group had 46,000 fingerlings at start. This number was reduced to 30,000 on July 5. On August 2, 10,000 were removed from each group.

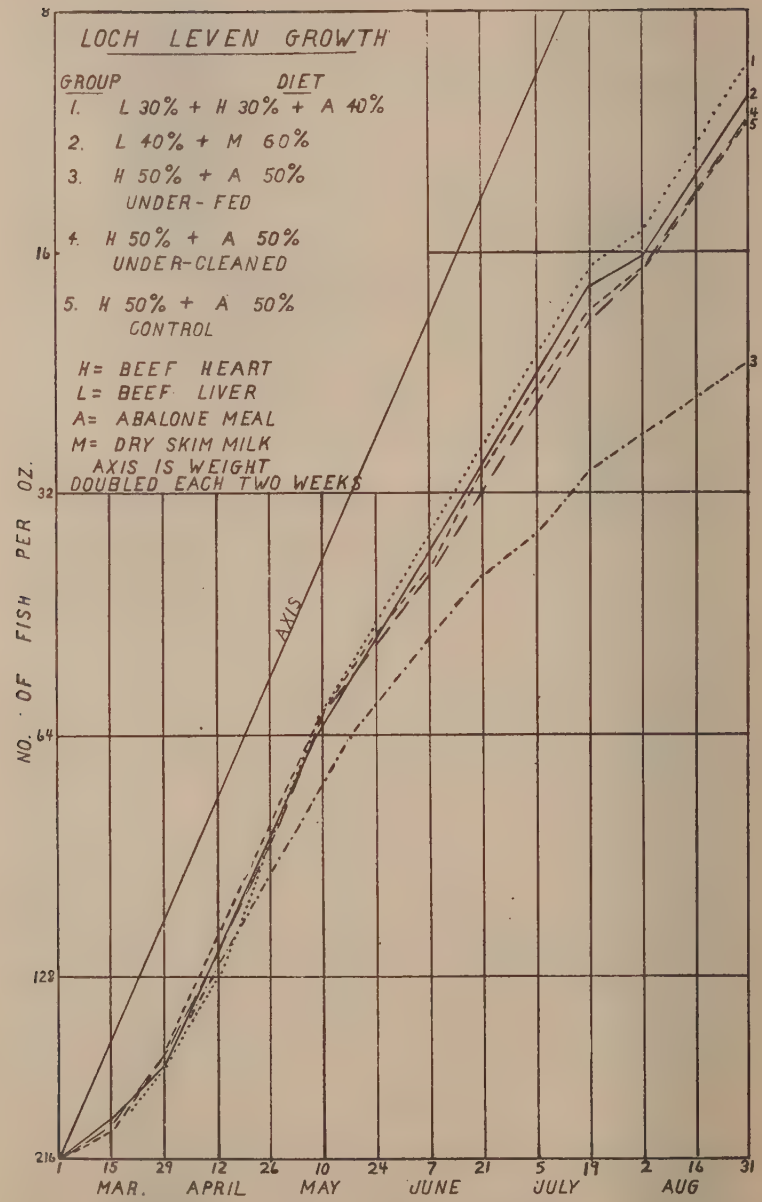


FIG. 40. Growth curve comparing the Loch Leven diets with an "axis" which represents a doubling of weight each two weeks. Each group had 46,000 fingerlings at start. This number was reduced to 30,000 on July 5. On August 2, 10,000 were removed from each group.

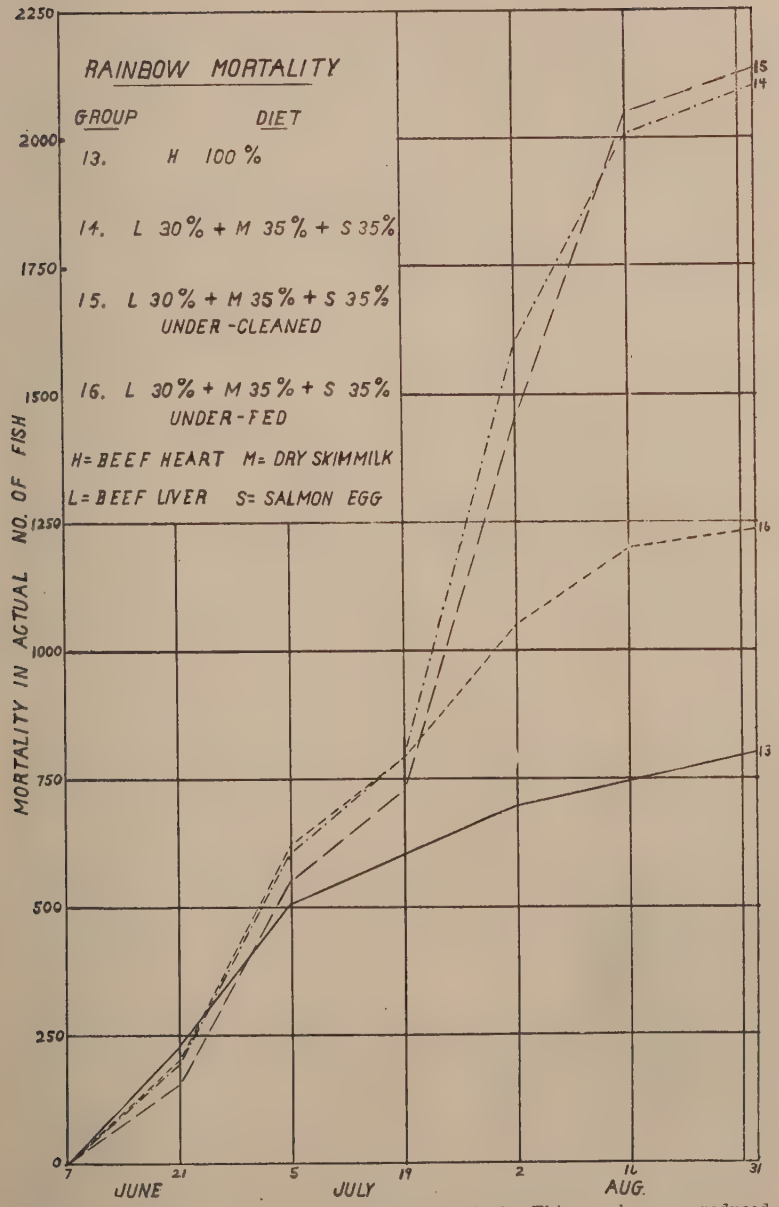


FIG. 41. Each group had 46,000 fingerlings at start. This number was reduced to 30,000 on August 16.

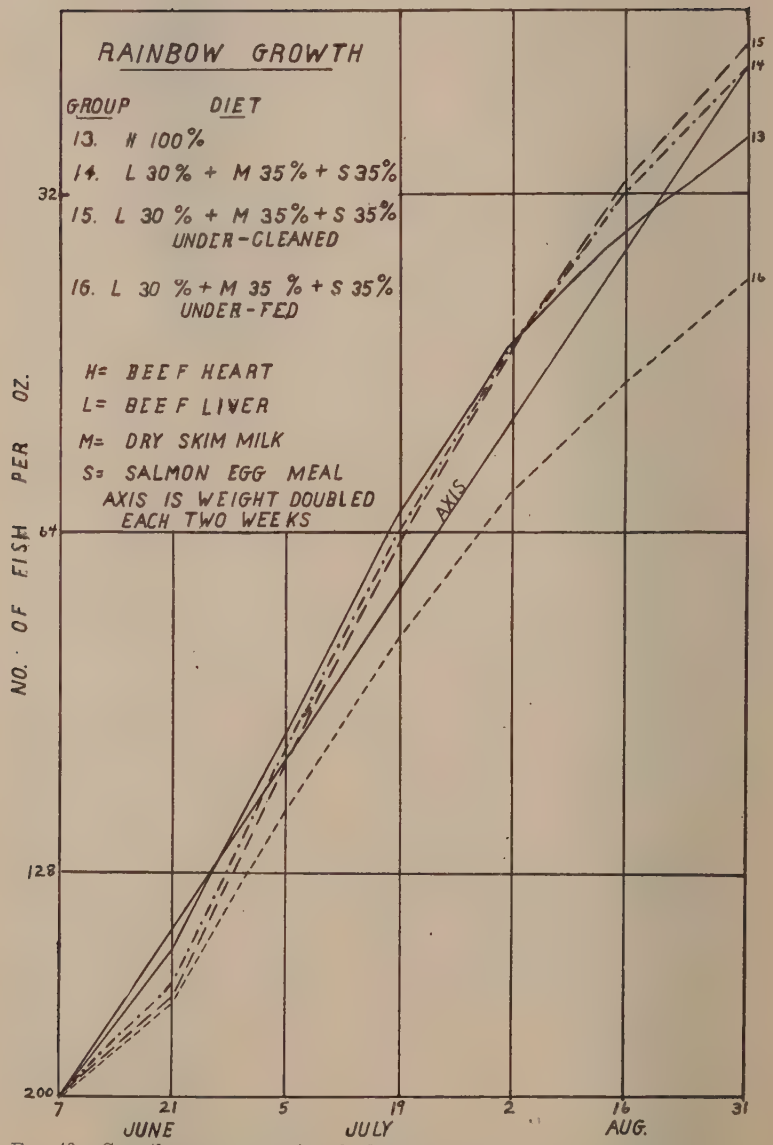


FIG. 42. Growth curve comparing the Rainbow diets with an "axis" which represents a doubling of weight each two weeks. Each group had 46,000 fingerlings at start. This number was reduced to 30,000 on August 16.

PROGRESS REPORT OF TROUT FEEDING EXPERIMENTS, 1935

By J. H. Wales and R. C. Lewis

This is the second report * of experiments which are being conducted at the California Division of Fish and Game Experimental Trout Hatchery located at Mt. Shasta.

These experiments are designed primarily to improve the type of food and the feeding methods now being used in the state hatcheries. However, other problems relating to the health of hatchery trout are being studied.

The recent advance in price of fresh meats has made it more apparent than ever before that cheap substitutes should be utilized. Previous investigators have found certain dry meals to be good trout foods and we have reached the same conclusions in our experiments of 1934 and 1935. We have found that these meals are nutritionally adequate and can be used economically for fingerlings after about the first six weeks of feeding. We have shown, however, that the present method of feeding these meal combinations through dippers with perforated bottoms is not practical for young fingerlings and the widespread use of meal substitutes, must wait until a better feeding method has been devised. Experiments with this object in view are being conducted at the present time.

OBJECTS OF EXPERIMENTS

The experiments to be reported upon in this paper were designed to: 1. Compare beef heart with beef liver when these were fed alone and when they were fed in combination with dry animal meals. 2. To determine the effect of certain diets upon Eastern Brook and Rainbow as well as upon Loch Leven fingerlings, which were used exclusively in the 1934 experiments. 3. To observe the results of underfeeding fingerlings. 4. To discover what the effect would be upon the health of fingerlings if the troughs were not cleaned as much as they are at present in California. 5. To see whether fingerlings kept in black troughs would be more healthy than those kept in the usual white troughs.

DESCRIPTION OF THE EXPERIMENTAL FISH AND THEIR CARE

The Loch Leven or Brown trout eggs were spawned from the brood stock at Mt. Shasta. Those used in the experiments were taken November 20, 1934, from unselected fish. Their size was 191 per ounce; 32,000 of these were placed in each of ten wire hatching baskets. Before hatching on January 16, 1935, this number was reduced to 25,000. Before they began to feed the number was further reduced to 23,000 per trough. This of course means 46,000 fish per experimental group as each group is composed of a tandem pair of troughs. Each trough is 16′ x 16″ and holds about 80 gallons of water. The inflow is 15 gallons per minute. On July 5, each trough of Loch Leven fingerlings

* California Fish and Game, Vol. 21, No. 2, April, 1935, pp. 110–124.

was thinned down to 15,000 fish. On August 2, 5,000 fish were removed from each trough. The experiment was concluded on August 31.

The Eastern Brook eggs were received in the eyed stage from the Klamath hatchery, in Oregon, on December 22, 1934. Their size was 400 per ounce; 25,000 eggs were placed in each of fourteen hatching baskets. On February 13, just before the fry started to feed, they were thinned to 23,000 per trough. On May 29, each trough of Brooks was thinned to 15,000 fish. On June 26, experimental groups Nos. 6, 7, 8, and 9 were thinned by a removal of 5,000 fish from each trough. On July 24, groups Nos. 7, 8, and 9, were thinned by a removal of 5,000 fish from each trough. The experiment was concluded on August 31.

The Rainbow were received on April 9, 1935, as green eggs, from the Klamath river. They measured 206 per ounce; 30,000 eggs were placed in each of eight hatching baskets. On May 16, just before hatching, the number per basket was reduced to 25,000. Before the fish started to feed each trough was reduced to 23,000 fry. On August 16, each trough was reduced to 15,000 fish. The experiment ended on August 31.

Samples of fish from each trough or two samples from each experimental group were weighed at the time feeding began and at two week intervals thereafter. While the fish were small, two ounces was a fair sample but as they grew the number of ounces was gradually increased to twenty. At least one hundred fish were counted at each weighing.

The troughs were cleaned in the customary manner except the so-called undercleaned troughs. These had the screens cleaned every day but were scrubbed only once a week. The screens of the control troughs were cleaned each day and the troughs themselves were scrubbed on alternate days. The water temperature averaged 48° F., ranging from 38° to 54° during the season. The amount of slime which grew on the troughs was never as great as though the water had been warmer. However, it it interesting to note that the troughs fed on a liver combination had much more slime than those fed on a heart combination. The undercleaned Rainbow group which was fed a combination of liver-dry skim milk-salmon egg had slimy troughs in a week's time while the undercleaned Loch Leven fed on heart and abalone did not. It was without doubt the liver in the diet which caused the formation of slime.

LIST OF EXPERIMENTAL GROUPS

Group No.	*Species*	*Food*	*Care*
1.	Loch Leven	30% liver, 30% heart, 40% abalone	regular
2.	Loch Leven	40% liver, 60% dry (d.) skim (s.) milk	regular
3.	Loch Leven	50% heart, 50% abalone	underfed
4.	Loch Leven	50% heart, 50% abalone	undercleaned
5.	Loch Leven	50% heart, 50% abalone	regular
6.	E. Brook	100% heart	regular
7.	E. Brook	30% liver, 35% d.s. milk, 35% sal. egg	regular
8.	E. Brook	30% liver, 35% d.s. milk, 35% abalone	regular
9.	E. Brook	50% liver, 50% salmon egg	regular
10.	E. Brook	50% heart, 50% abalone	underfed
11.	E. Brook	50% heart, 50% abalone	regular
12.	E. Brook	50% heart, 50% abalone	black trough
13.	Rainbow	100% heart	regular
14.	Rainbow	30% liver, 35% d.s. milk, 35% sal. egg	regular
15.	Rainbow	30% liver, 35% d.s. milk, 35% sal. egg	undercleaned
16.	Rainbow	30% liver, 35% d.s. milk, 35% sal. egg	underfed

DESCRIPTION OF FOODS

Beef Liver and Heart: These were fed fresh. Cost of liver—8¢ to 15¢ per lb. Average for the season was 11.3¢ per lb. Cost of Heart—9¢ to 20¢ per lb. Average for the season was 12.8¢ per lb. Fat composed 24% of the weight of heart. This was removed before feeding. The cost of the heart included the fat but the weight of heart fed the fish did not include it.

Abalone meal: This is a dry meal made from abalone scraps from the packing plants at Monterey, California. It is ordinarily put up in three grades, according to the size of particles. It contains about 5% moisture. Cost—6¢ per lb.

Salmon egg meal: This is composed of dry, ground salmon eggs graded into three sizes. The moisture content is about 2%. Cost—7¢ per lb.

Dry skim milk: This product is in the form of granules of various sizes. Its moisture content is about 5%. Cost—6½¢ per lb.

PREPARATION OF FOOD

Feeding was started just before the fish began to swim up from the bottom. From this time until the fish weighed 80 per oz. the liver was thawed out and ground twice through the $\frac{5}{64}$″ plate. From this time until they weighed 25 per oz. the liver was ground once through the $\frac{5}{64}$″ plate, then the ⅛″ plate was substituted and used for the remainder of the experiment. The frozen heart was ground three times through the $\frac{5}{64}$″ plate until the fish weighed 170 per oz. when the number of grindings was reduced to two. When the fish weighed 30 per oz. the heart was ground but once through the $\frac{5}{64}$″ plate and this was not changed during the experiment. It is an important fact that heart grinds much more easily when frozen than when thawed out.

The abalone, salmon egg and dry skim milk were gradually changed from the finest grade to the coarsest as the fish grew. Even the change from one size of meal to the next was made gradually by mixing the two grades.

The meals were mixed into the ground meat by hand and enough water was added to give the combination the right consistency after it had soaked for three hours or more.

All of the foods were fed through the customary dippers which have perforated tin bottoms. A dipper with a small sized hole was used while the fish were young and as they grew dippers with larger holes were substituted. Five sizes were used during the experiment until the fish were about 30 per oz. when a dipper with a ¼″ wire cloth bottom was substituted.

In the underfed groups the amount fed was the same as the controls for the first four to six weeks when the controls were given an increase. The underfed lots were given an increase somewhat later and were fed proportionally less and less until at the end of the experiment they were being fed about one half that fed the controls. In this experiment we tried to duplicate the methods of some hatcherymen who regularly underfeed.

MORTALITY

There are two features relating to mortality which should be pointed out. The heavy death rate in the Loch Leven and Eastern Brook was caused by an excess of abalone in the diet. In certain of the Rainbow groups the high mortality was apparently caused by gill irritation from the salmon egg meal and dry skim milk.

One of the producing hatcheries at Mt. Shasta fed 50% beef liver and 50% abalone during 1935. A peculiar disease developed in these fish which was the same as that in the heart and abalone fed fish in the Experimental Hatchery. This would not seem strange had not the liver and abalone fed Loch Leven in the Experimental Hatchery in 1934 been very healthy and entirely free from this disease. It might appear that the abalone meal of 1935 had some poison in it which was not present in 1934. However we see that the Loch Leven in diet No. 1 were unusually healthy in 1935. If it were considered wise to use abalone in the future, experiments should be run to determine the correct percentage. The abalone disease was entirely new. No organism could be found and the gradual weakening and final death made it appear to be the result of some nutritional deficiency or a cumulative poison. The disease became noticeable in the Eastern Brook mortality during May and in the Loch Leven somewhat later. The symptoms were as follows: The diseased fish kept near the lower end of the troughs and would lie on the bottom, frequently gasping and shaking their heads. In some individuals the head was bent sharply to one side, while in others one side of the body would be black with a sharp line of division from the light side. The operculae bulged out markedly. Swimming was often erratic.

When there was no question about the character of the disease the abalone was taken from the diet and beef heart alone was fed. The Eastern Brook improved and the mortality was reduced for about two months but at the end of this time the death rate began to rise once more. The Loch Leven were not put on a heart diet until August 18, and no improvement was observed at the end of the experiment on August 31.

In the Rainbow it will be seen that the high mortality occurred in the diets containing salmon egg meal and dried skim milk. There is considerable fouling of the water when these meals are fed through a dipper and it seems more than likely that this caused the serious gill swelling. The irritation caused by these meals occurred soon after the fish start to feed and may be either chemical or mechanical in nature. In this disease no organisms are found except occasionally when an individual has a secondary invader. It seems almost certain that if these foods can be fed without polluting the water, this gill irritation will be obviated. Another point brought out in the 1935 experiments was that beef heart is a fine food on which to start fingerlings but when continued for more than two months the growth is seriously impaired and the death rate is increased. In addition the cost of heart makes it wise to use cheap substitutes. Experiments are under way in the Experimental Hatchery to determine how long it is wise to feed heart and how it is best to make the change to a liver-meal diet.

Looking at the graph of the Rainbow mortality it is interesting to note that the underfed group had far less deaths than the control and undercleaned. This is probably due to the fact that when there is less feeding there is less pollution. However it is not clear why the mortality in the underfed Loch Leven was less than in the control and why the reverse was true in the Eastern Brook. In the Loch Leven there was none of this gill irritation which was so harmful to the Rainbow.

GROWTH

It can be seen from the graphs that the Lock Leven are comparatively slow growing, while the Brooks and Rainbow tend to double their weight every four weeks during the first few months. The various diets in the Loch Leven are quite similar in respect to growth, excepting, of course the underfed group. In view of these facts the Loch Leven make poor experimental animals for food tests. The Brooks, however, make excellent experimental fish. They react to slight differences in foods and are superior to spring spawning Rainbow because they are older at time of planting.

The growth graph for the Eastern Brooks shows the best results to be with the liver-salmon-egg; liver-dry skim milk-abalone; and liver-skim milk-salmon egg diets. The poor growth in the heart-abalone fed group was due largely to the disease. The relatively poor growth shown by the 100% heart fed fish is in marked contrast to the growth of the fish fed the liver and meal combinations. The difference here is due solely to the foods as such, no diseases played any part.

The fish kept in the black, asphaltum painted troughs did not grow any better than the white controls, although the mortality was somewhat less. However it is so much harder to care for fish in black troughs and to detect incipient diseases that the writers unhesitatingly condemn them.

COST

Attention is called to the columns in Table 1, titled "Cost per lb. of fish," "Cost per 1000 fish" and "Size of fish at end of experiment." These show several features which should be of interest to fish culturists. Providing there is a low mortality, the cost per lb. of fish is less in meal combinations where the liver or heart content is low. Thus we see that the combinations of liver-dry skim milk-salmon egg and liver-dry skim milk-abalone produced a pound of trout far cheaper than any of the others. Thirty per cent dry weight of liver in these combinations seems to be all the fresh meat necessary; any more is a waste of money.

Another fact is that when disease kills off large numbers of fish the cost of raising a pound of trout goes up in proportion to the pounds of fish which died.

The 100% heart diets for the Brooks and Rainbow were also very high priced. We see that diet No. 6 (100% heart) was more than five times as expensive as No. 7 (liver-dry skim milk-salmon egg).

Naturally enough, we find that when fish are underfed the cost of their food per 1000 fish is low, but we also can be sure that they won't grow very rapidly. It may be argued that a large number of small fish is just as good as a smaller number of larger fingerlings.

The answer to this is that fish should not be underfed; instead they should be planted out at an earlier date.

SUMMARY

1. Eastern Brook, Loch Leven and Rainbow fingerlings were used in these experiments.
2. The experiments began with the eggs and continued until the fingerlings were from three to eight months old. This is the usual length of time fish are kept in the California hatcheries before planting.
3. Each of the sixteen experimental groups was composed of two hatchery troughs. Each trough contained 23,000 fish when feeding began, or a total of 46,000 fish in each experimental group. This number was reduced at intervals as the fish grew and became crowded. This procedure is exactly the same as the one followed in the producing California hatcheries.
4. Samples of fish from each trough were weighed every two weeks to determine their growth rate. The amount of food given each lot, and the number of dead fish in each trough was recorded daily.
5. The diets composed of 50% beef heart and 50% abalone meal produced a disease which may have been due to a cumulative poison or to a nutritional deficiency.
6. The pollution of the water caused by fine particles of dry skim milk and salmon egg in the food is harmful to the gills of very young trout, especially Rainbow. For this reason it is best to start fingerlings on 100% heart and between one and two months later change to a liver and meal combination. Heart can not be combined satisfactorily with dry meals.
7. Salmon egg meal and dry skim milk are excellent foods when properly used. They can be combined with a small percentage of liver to give rapid growth at low cost.
8. In our experiments the fish which were underfed, simply grew more slowly than those which were given all they wanted to eat. However under other water conditions this underfeeding might have caused disease.
9. Fish kept in troughs which were scrubbed once a week were found to be just as healthy and grew as well as fish kept in troughs which were scrubbed on alternate days. These experiments were conducted in relatively cold water and the results might have favored the cleaner troughs had the experiments been run in warmer water.
10. Although our results did not show a marked difference between the black and white troughs it was found that fish in black troughs are much harder to care for and that diseases are much more difficult to detect.

Table 1

Diet No.	Species	Ingredients Percentage by dry wt.	Pounds of food, dry weight, to produce a pound of Trout	Number fish per ounce at end of Exp., Aug. 31	Total mortality Fingerlings	Per cent mortality Fingerlings	Probable mortality if all fish had been kept*	Per cent egg mortality	Per cent fry mortality	Pounds of fish produced	Cost per pound of fish	Cost per 1,000 fish
1	Loch Leven	30% L, 30% H, 40% A	1.18	9.30	751	1.63	782	25.0	3.0	213.8	$0.32	$2.24
2	Loch Leven	40% L, 60% M	1.65	10.75	801	1.74	856	27.5	3.0	143.4	.32	1.50
3	Loch Leven	50% H, 50% A (underfed)	1.30	21.75	1,648	3.58	2,213	30.5	3.0	99.5	.35	1.12
4	Loch Leven	50% H, 50% A (undercleaned)	1.42	11.65	2,222	4.83	3,938	24.0	3.0	166.0	.40	2.18
5	Loch Leven	50% H, 50% A (control)	1.40	11.70	2,400	5.22	3,960	26.0	3.0	167.5	.40	2.19
6	E. Brook	100% H	1.39	10.25	1,759	3.82	2,570		2.0	161.3	.63	4.11
7	E. Brook	30% L, 35% M, 35% S	.74	3.59	1,225	2.66	1,368		2.0	348.1	.12	2.37
8	E. Brook	30% L, 35% M, 35% A	.79	3.66	1,115	2.42	1,197		2.0	340.7	.13	2.48
9	E. Brook	50% L, 50% S	.80	3.88	1,079	2.35	1,205	Received as eyed eggs	2.0	312.1	.20	3.25
10	E. Brook	50% H, 50% A (underfed)	1.38	19.60	4,759	10.35	6,217		2.0	97.4	.50	1.61
11	E. Brook	50% H, 50% A (white trough)	1.69	14.65	3,825	8.32	4,653		2.0	131.8	.65	2.78
12	E. Brook	50% H, 50%A (black trough)	1.75	15.25	3,219	7.00	4,039		2.0	127.5	.67	2.76
13	Rainbow	100% H	1.08	28.75	807	1.75	839	14.0	.8	79.3	.58	1.14
14	Rainbow	30% L, 35% M, 35% S	.88	24.92	2,085	4.52	2,117	12.5	.8	90.8	.17	.40
15	Rainbow	30% L, 35% M, 35% S (under cleaned)	.84	23.65	2,131	4.63	2,172	13.0	.8	95.5	.17	.40
16	Rainbow	30% L, 35% M, 35% S (underfed)	.81	36.55	1,239	2.69	1,258	12.5	1.0	57.6	.16	.22

H=Beef heart. L=Beef liver. A=Abalone. M=Dry skim milk. S=Salmon egg meal.
* This includes the fish which were removed before end of experiment.

THE HOT CREEK REARING PONDS*

By P. R. NEEDHAM, Ph.D., Associate Aquatic Biologist,
U. S. Bureau of Fisheries

Over in eastern California in the upper end of the Owens Valley thirty-eight miles north of Bishop, and in the shadow of Mt. Morrison which towers some 12,000 ft. in elevation, lie the Hot Creek rearing ponds. Fed by perpetual springs running in temperature from 52° F. to 68° F. the year round, three separate spring runs have been utilized for experimental rearing ponds by the California Trout Investigations. This research unit, working on practical fisheries problems in

FIG. 43. Watercress beds in natural ponds at Hot Creek rearing ponds.

California began active field work in 1932 as a joint investigation between the California Division of Fish and Game and the Federal Bureau of Fisheries.** All phases of the work have been conducted in close cooperation with Dr. J. O. Snyder, Chief of the Bureau of Fish Conservation.

FISH CULTURAL ADVANTAGES OF HOT CREEK AREA

No other spot in California offers such an abundant supply of water of even year-round temperature and natural foods. Over twenty

* Published by permission of the U. S. Commissioner of Fisheries.

** Thanks are due officials of Stanford University who have supplied ample working headquarters for the investigations as well as the loan of much useful equipment.

springs occur in three separate runs with a combined flow of 30 sec. ft. of water. The spring runs contain luxuriant growths of watercress and other aquatic plants inhabited by vast numbers of shrimp (*Gammarus*), mayfly nymphs, caddicefly larvae and pupae, snails, and other organisms. Over one-quarter of a pound of pure shrimp containing 5,063 individuals were taken from an area of one square foot in the center of a watercress bed in one of the ponds in 1934. Such tremendous amounts of water foods make it possible to rear trout to good size at little or no cost for food. Some artificial food will have to be fed such adult brood fish as are held for egg taking purposes but a considerable saving in food is possible as compared to the usual hatchery site in California. The lay of the ground is such as to permit almost unlimited pond construction in the three runs if the state should desire to enlarge the fish raising operations at this place in the future.

HISTORY OF THE DEVELOPMENT OF THE HOT CREEK AREA

The Rainbow Club of Bishop, California, first realized the great possibilities of Hot Creek for fish cultural activities and constructed the first pond on the property after securing authority from the City of Los Angeles which owns the land. This club fenced in the 55 acres enclosing the area of the springs in 1930 and reared the first trout planted there.

In the summer of 1931, Mr. A. C. Taft visited the springs and recommended that the Division of Fish and Game lease the property from the City of Los Angeles, and that the rearing experiments on natural foods described below be undertaken. Following these recommendations a lease was secured at $1.00 a year from the City of Los Angeles and in November, 1931, a two-room cabin with tool shed and two ponds, each between 300 and 500 ft. long, with dirt filled dams were constructed.

In the summer of 1934, in order to provide facilities that would permit experimental work on the rearing of selected strains of rainbow trout the following items were built there, viz., twelve concrete raceways, 20 ft. long by 4 ft. wide for rearing, spawning, and sorting trout; two additional ponds with dirt-filled dams; three-car garage for equipment with meat grinding room and small laboratory; and direct road from the main Los Angeles-Reno highway one-half mile into the ponds. The last named item was constructed through cooperation of the U. S. Forest Service using CCC labor. In the fall of 1934, a small twelve trough experimental hatchery was constructed with water supplied from a 57° F. spring which now gives proper facilities for eyeing and hatching eggs.

In the fall of 1935 further improvements were installed that were designed to improve living as well as operating conditions. These consisted of an additional room on cabin the same size as the old two-room cabin supplied with running water; telephone line; work shelter at raceways for winter spawning or sorting operations, woodshed, and garage on main highway to enable the person in charge of the ponds to get to Bishop for supplies in the winter time when the road to the ponds is closed by snow. The Division of Fish and Game supplied all materials for these improvements while the Forest Service, through Mr. Roy Boothe, Supervisor of the Inyo National Forest, furnished all labor.

The Hot Creek ponds now represent, therefore, a three-way cooperative project between the Division of Fish and Game, Forest Service, and the U. S. Bureau of Fisheries.

The plant as it now stands, represents a fairly complete unit for experimental or production purposes. Considerable numbers of fish reared in the experimental work there have, at the conclusion of the experiments, been planted into many intensively fished waters lying in the Hot Creek area. Among these are the June Lakes, Mammoth Lakes, Convict Lake, Owens River, and Hot, Hilton, Convict, and Mammoth creeks. The Hot Creek ponds offer almost ideal conditions for rearing trout for planting the waters in that vacationists' wonderland of lakes and streams adjacent to the headwaters of the Owens River.

FIG. 44. Hot Creek Rearing Pond No. 1 in winter. White Mountains on California-Nevada line in distance.

EXPERIMENTAL WORK IN 1932 AND 1933 *

In these years two ponds only were operated with the object of determining growth and survival rates in relation to stocking intensity when rearing trout in ponds on only natural foods furnished in the ponds themselves.

In Tables 1 and 2 below, are summarized the results obtained with rainbow and loch leven trout in 1932 and 1933, respectively. In Table

* Thanks are due Mr. A. C. Taft and Mr. Leo Shapovalov of the Trout Investigations staff under whom the results in 1932 and 1933 were obtained at Hot Creek. Mr. Leo Shapovalov and Mr. Leonard Wilder cared for the ponds in the summers of 1932 and 1933, respectively. Mr. Carleton Rogers, assisted by Mr. Francis Sumner, was in charge of the ponds under the writer's direction from June, 1934, to October, 1935. Since the latter period Mr. Robert Lewis has been in charge of the field work assisted by Mr. Leo Erkkila. Many other persons have given much assistance from time to time. Thanks are duly rendered to these as well as those mentioned by name above.

1, the most significant observation is that a survival rate of approximately 40 per cent was obtained both seasons regardless of the widely varying numbers planted in the ponds. For instance, in 1932, 6,031 rainbows averaging 1.2 inches in length were planted in pond No. 1 and 2.7 months later when the pond was drawn down 43.26 per cent were recovered. Likewise, in 1933, 29,748 loch leven averaging 1.3 inches in length were planted and 3.5 months later 45.22 per cent were recovered. The only noticeable difference between these two lots of fish was the rate of growth per month, the rainbows averaging 0.63 inches per month in 1932 and the loch leven, 0.48 inches per month. The logical conclusion from these observations is that the 29,748 loch leven trout planted in 1933 was somewhat in excess of the available food supply, which resulted in slower growth per month. This is evident with both lots of fish planted in 1933, for the average growth in 1932 for both lots was 0.63 inches and in 1933, 0.46 inches. It should also be stated that this difference in growth rate may have been partly due to the inherent capacity of each species for growth. It is generally believed by fish culturists that loch leven are slower growing than rainbows when young.

Table 1. Hot Creek Rearing Pond Experiments, 1932 and 1933

Year	Pond No.	Number planted	Date	Number recovered	Time interval	Per cent survival	Species
1932	1	6,031	July 8	2,609	2.7 mo.	43.26	Rainbow
1932	2	3,042	July 8	1,188	2.7 mo.	39.05	Rainbow
1933	1	29,748	June 15	13,451	3.5 mo.	45.22	Loch Leven
1933	2	19,832	June 15	8,311	3.5 mo.	41.91	Loch Leven

Table 2. Growth of Trout in Hot Creek Ponds, 1932 and 1933

Year	Pond No.	Length in inches					Average growth in inches per month
		At planting	One month later	Two months later	Three months later	At draining	
1932	1	1.2	1.7	2.3		2.9	0.63
1932	2	1.2	1.7	2.3		2.9	0.63
1933	1	1.3	1.4	2.1	2.9	3.0	0.48
1933	2	1.3	1.4	2.2	3.0	2.9	0.45

An average growth of approximately half an inch a month in water at 63° F. over these two seasons' experiments on natural foods raises the question as to what growth could be obtained in water at the same temperature when feeding artificial food. Such an experiment was conducted in the summer of 1935 and is worth recording here.*

Two lots of 100 rainbows averaging 5.1 inches in length were placed in two separate raceways and kept under identical conditions in water at 63° F. One lot was fed an artificial diet of fresh liver, abalone meal, and salmon egg meal. The other lot was fed only shrimp collected by hand in the watercress beds. All the fish in each lot were weighed and growth determined by measurements of each fish in each lot at seventeen day intervals. A record of the total food fed each lot

* This experiment was carried on by Mr. Leo Erkkila under the writer's direction at the Hot Creek ponds.

each day was likewise recorded over the eighty-five day period the experiment was run.

The results are illuminating. The lot fed on artificial food averaged 0.99 inches growth per month or approximately one inch. The shrimp fed lot grew somewhat slower, averaging only 0.82 inches per month. These are tremendous growth rates and make possible a comparison with the rates obtained on natural food in ponds in 1932 and 1933 where the growth rate was 0.63 inches and 0.46 inches, respectively, as noted above. In these years, the fish at planting averaged 1.2 and 1.3 inches respectively. Fish at this size naturally grow slower than fish at five inches, which was the average size of the rainbows at the start of the artificial feeding experiment. In addition, the latter fish were relieved of all necessity of hunting for their food because it was merely thrown into the raceways to them while the former

FIG. 45. Experimental hatchery at Hot Creek with dam that furnishes water supply to same.

had to seek it out in competition with their brothers and sisters in natural ponds.

It was also determined from the shrimp fed lot of rainbows that it took 9.42 lbs. of shrimp (wet weight) to produce a pound of trout. With the lot fed 30 per cent liver, 35 per cent abalone meal, and 35 per cent salmon egg meal, it took 3.00 lbs. of this mixture (natural weight) to produce a pound of trout at a cost of $0.28 per pound of trout raised. The cost per pound of food fed was $0.094.

A growth rate of approximately one inch a month on artificial food and half an inch a month on natural food in ponds is a clear demonstration of what can be accomplished in way of raising fish at the Hot Creek ponds. Lack of space here prevents further discussion of growth

rates obtained from rearing operations on both natural and artificial foods in ponds and raceways since 1933.

Having found that it was possible to eye and to hatch rainbow eggs as well as to rear them after hatching in Hot Creek waters, the next step undertaken was to determine whether or not good eggs could be produced in female rainbows reared and held in water of various temperatures at Hot Creek. Experiments to determine this are under way now. This work naturally requires year-round operation and the new equipment constructed in 1934 and 1935 now permit all-year operations of the Hot Creek plant.

OBJECTS OF EXPERIMENTAL BREEDING OF RAINBOW TROUT

As Dr. J. O. Snyder has frequently pointed out, there is a definite shortage of rainbow eggs in California at the present time and very probably this condition will become worse rather than better in future years. To start now to develop fine, select, strains of fall-spawning rainbow brood stock is to anticipate future needs with high egg-yielding, rapid-growing fish that will make possible planting of the best type of fish available. It costs no more to rear and to feed fine stocks of trout than it does nonselected, slow-growing lots of fish that are far less effective in maintenance of sport fishing when planted in streams. At the New Jersey State Hatchery in Hackettstown, N. J., selective breeding of eastern brook trout have so increased egg yields that now they have to rear and feed only one-fourth the number of breeders to secure the same number of eggs as were obtained before from nonselect, straight-run breeders.

Fall spawning rainbows are desired as they will make available to the state for planting purposes, larger fingerlings than can be reared in one growing season from normal spring-spawning rainbows. Listed below are three strains of fall-spawning rainbow trout that are now being reared at Hot Creek. It should be emphasized at this point that Hot Creek is the only area we know of in the State of California where such experiments with fall-spawning rainbow could be conducted. If such trout were held in the cold water that obtains at most California hatcheries in the winter, in all probability such fish would revert to their spring spawning habit. So far as the writer is aware, it has been possible to develop such strains only where spring water from 52° F. to 60° F. is available.

The following strains of fall-spawning rainbows are being utilized in the present experiments:

Strain	*Spawning period*
Neosho, Mo. rainbow	November
Forest Home, California, rainbow	December
Springville, Utah, rainbow	October

Just as soon as select stocks are developed they will be made available to the California Division of Fish and Game. Selective breeding experiments are just as necessary to, and will prove just as useful to, the state fish cultural program as this process has been to breeders of fine cattle, sheep, hogs, or other agricultural products. To quote

Dr. H. S. Davis, Chief of Aquicultural Investigations of the U. S. Bureau of Fisheries, on this subject:

"To what extent the rate of growth can be increased by selective breeding is, of course, a matter for conjecture. It is evident that there must be a limit to the increased growth which can be obtained by this means, but it is scarcely probable that this limit has been reached in two generations of rigid selection. The progress already made is truly remarkable, and it is now possible by the use of selected stocks and improved diets to rear brook trout in one year to a size which ordinarily requires from three to four years under natural conditions. In fact, at temperatures which are most favorable for growth it is possible to rear brook trout to a length of 9 to 10 inches by the end of the first summer.

FIG. 46. Adjusting water flow into a single pair of concrete raceways at Hot Creek.

"So far the experiments in selective breeding have dealt chiefly with brook trout, but similar experiments with rainbow and brown trout are now in progress. The results so far obtained indicate that these species are just as responsive to selection as is the brook trout."*

In connection with the development of select strains of rainbows, it is hoped that it may be possible to develop a more or less non-migratory strain of this species. This may be a mere day dream but in the State of California where downstream migration of trout often causes huge losses due both to irrigation and power diversions, planting of nonmigratory rainbows would mean an immense annual saving of trout to augment anglers' catches and in the end mean considerably less fish would have to be planted to maintain sport fishing. It may not be possible to find a nonmigratory type of rainbow but at least by

* Davis, H. S. 1934. Growth and heredity in trout. Trans. Amer. Fish Soc., Vol. 64, pp. 197–201.

starting with such strains as have been forced to forego downstream migration due both to climatic and geographic barriers for centuries the chances would seem fairly good to secure such fish. Natural selection operating in nature over a long period of time would naturally assist in the production of just such type of fish. Fish culturists in other states have long been interested in the development of such strains though to date little has been accomplished along this line of attack.

While the Hot Creek plant is operated primarily for experimental purposes, in 1935, 27,300 trout having a total weight of 717 lbs. were planted into nearby open fishing waters. These fish were culls from grading operations with the select strains as well as fish produced from egg hatching experiments. Starting next season it will be possible to produce a considerable number of trout for purely planting purposes without hampering in any way the experimental program. Last summer some 4,000 of the culls from experimental lots were used in two planting experiments after marking the fish by removal of certain fins. In the latter connection it should be stated that the Hot Creek rearing ponds offer a fine opportunity to link up field problems with purely hatchery problems enabling one to follow fish from hatchery life through to their demise in anglers' creels by means of marking experiments.

In conclusion, though only incomplete results have been obtained to date on the brood stock experiments under way at Hot Creek, it is hoped that this work will ultimately prove of great benefit and offer material aid, to California's restocking problems.

HATCHERY TROUGH AERATORS

By Paul A. Shaw

During the summer of 1935 a study was conducted to determine the efficiency of aerators in use in hatchery troughs and to develop a simple and practical aerator of higher efficiency.

The purpose of an aerator is to provide oxygen absorption in a water supply initially deficient in dissolved oxygen or to provide reabsorption of oxygen to replenish that consumed by the respiration of fish in an upper trough. In general, the water supplies as delivered to the head troughs of California hatcheries are substantially saturated with air and the chief benefit of an aerator is derived by use between upper and lower troughs. In instances where the water supply is deficient as received at the hatchery, it would appear better to install an aerating device for the entire water supply and discontinue the use of individual aerators for the upper troughs.

It has been frequently observed that fish in lower troughs suffer a heavier mortality and are in poorer condition than those in the upper. In heavily loaded troughs it is reasonable to suppose that an oxygen content below the optimum may be an important factor contributing to the reduced vitality of fish in lower troughs. In fact, considerable data has appeared in various publications indicating that certain diseases and lowered vitality are associated with the use of water having a low oxygen content.

The benefits to be derived from an aerator of higher efficiency, therefore, include the probability of increased resistance; lower mortality and better growth; and, when necessary, the ability to hold more fish or the same number of fish to a larger size on a limited water supply.

The scope of aerator design and the degree of reaeration are limited by several factors. Of first importance is the fact that the available fall between the surface of the water in the upper and lower trough is only 9 to 11 inches. In addition, it is necessary to have a fairly simple design, of relatively low cost, small enough not to encroach on the available trough space or interfere with the workmen's duties. Further, the aerator must be designed so that it will not clog with sediment or allow fish to easily ascend to the upper trough.

BASIS OF COMPARISON

In order to study the aerators in use and work out an improved design it was essential to have a definite basis of comparison.

It can be readily shown that the actual amount of oxygen picked up is not a correct measure of an aerator's efficiency. For example, if a small quantity of salt is placed in water, only moderate agitation and a short period of time are required for complete solution. With continued additions of the same quantity of salt, the agitation and time required for solution will increase until at the saturation point no further salt will be dissolved. In the same way, water devoid of oxygen

will pick it up rapidly with agitation and exposure to the air, but near the saturation point the same procedure will result in the absorption of negligible quantities of oxygen. It is therefore evident that any one aerator may pick up widely varying quantities of oxygen with changing conditions.

A series of tests were first conducted to determine the relation between the amount of depletion and the reabsorption with fixed conditions in other respects. An experimental trough with an outlet one inch wide to carry the main flow of water, was equipped with a siphon of glass tubing to provide a separate flow of constant rate. Water flowing from the siphon fell a distance of 30 inches and was collected in a wooden receiver in which a constant water depth of 6 inches was maintained. Both the trough and the receiver were provided with a baffle set about 2 inches back from the respective outlets. The baffles served to mix the flow of water and insure the collection of representative samples for analysis. With the above setup, constant conditions were maintained for rate of flow, size of outlet, distance of fall and depth of receiving water. However, certain variations due to wind currents within the building undoubtedly occurred. The amount of oxygen depletion at the trough outlet was varied by changing the number of fish in the trough or by changing the total rate of flow. After each such change a period of 20 minutes was allowed to pass before collection of samples to insure a condition of equilibrium.

For each test, samples were collected from the inlet, outlet, and receiver and analyzed for oxygen content. The efficiency of the aerator at varying oxygen depletions was determined from the ratio between pickup and the depletion as expressed by the formula:

$$\text{Per cent Oxygen Recovery} = 100 \times \frac{\text{Oxygen Content in Receiver} - \text{Oxygen Content at Trough Outlet}}{\text{Oxygen Content at Trough Inlet} - \text{Oxygen Content at Trough Outlet}}$$

Since all the analyses of inlet water indicated a condition of complete saturation for the existing altitude and observed temperature, no correction was necessary for this factor. The results of two tests at each of three outlet saturations varying from 48 to 74 per cent, are given in Table 1.

TABLE 1

Oxygen content (parts per million)

Inlet	*Outlet*	*Receiver*	*Loss in trough*	*Pick up by aerator*	*Aeration efficiency percentage recovery*
8.95	6.65	7.80	2.30	1.15	50
8.90	6.55	7.70	2.35	1.15	49
8.85	5.70	7.50	3.15	1.80	57
8.85	5.70	7.40	3.15	1.70	54
8.40	4.00	6.25	4.40	2.25	51
8.30	3.95	6.30	4.35	2.35	54

It will be noted that the pickup by the aerator increased in proportion to the depletion in the trough, and that the final value of per cent oxygen recovered is practically constant for the range tested. This data therefore furnishes a definite basis for aerator comparisons by the analysis of three samples for each test from which to compute the aerator efficiency in terms of percentage oxygen recovery.

All subsequent comparisons of aeration efficiency were based on oxygen analyses of inlet, outlet, and receiver samples from which the

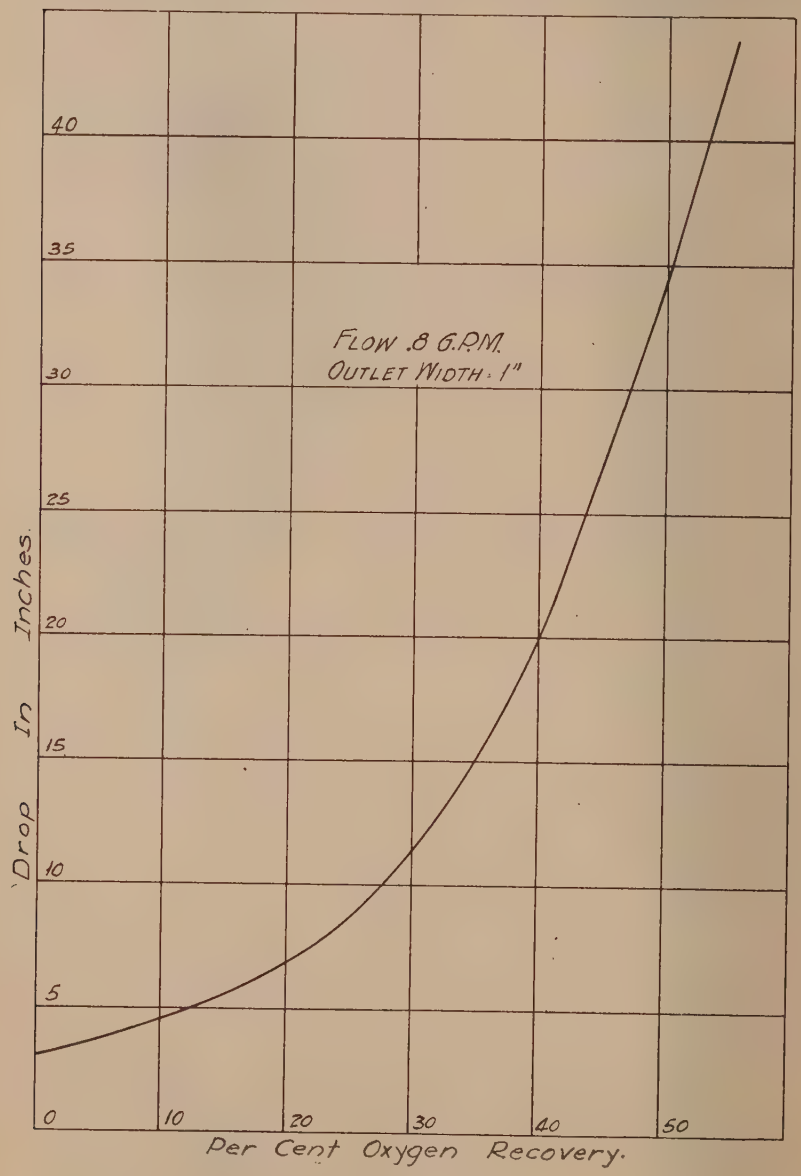


FIG. 47.

per cent oxygen recovery was computed. Whenever possible, a depletion approximating 40% was maintained at the trough outlet since

more accurate determinations of efficiency were possible from depletions of this magnitude than from smaller reductions.

AERATION BY DIRECT FALL FROM TROUGH OUTLET

Distance of Fall

Using the experimental trough with a flow of 0.8 gallons per minute through an outlet 1 inch wide, the aeration efficiency was determined for falls of 4 to 44 inches into a receiver having a 6-inch depth of water. Although the distance from upper to lower troughs in California hatcheries is limited to about 10 inches, it was important to determine the relative absorption for varying distances of fall as a basis for comparisons.

Figure 47 shows aeration efficiency plotted against inches of fall as determined from the above experiment. It should be noted that with the above conditions no measurable aeration would occur with falls of 3 inches or less. The amount of aeration is relatively high for the next few inches after which the rate gradually decreases for added distances of fall. The recovery for 44 inches was 55.5 per cent while that for a hatchery drop of 10 inches was 27.5 per cent.

These values, however, should not be considered fixed. First, because velocity increases with distance of fall and unless the depth of water in the receiver is increased correspondingly the maximum effect of aeration resulting from penetration is not obtained. Second, the amount of surface exposure will vary with the rate of flow per inch of outlet width and the value of 27.5 per cent could not be obtained in hatchery practice without widening the outlet width to 20 inches to give aproximately 0.8 gallons of flow per inch.

Figure 47 will be referred to again in discussing other aeration factors.

Rate of Flow per Unit Width

Another series of tests were conducted with the water level in the receiver fixed at 10 inches below the trough outlet and determinations made with varying rates of flow. Figure 48 shows per cent aeration efficiency plotted against rate of flow per inch of width for a drop of 10 inches. It should be noted that the amount of aeration falls off rapidly with increasing rates of flow, and the curve also indicates that flows of less than 0.8 gallons per inch will not increase the efficiency very much above the 27.5 per cent before indicated.

Table 2 was derived from Figure 48 and indicates the per cent oxygen recovery that can be anticipated in hatchery troughs for varying rates of flow with a 10-inch outlet width.

TABLE 2

Gallons per minute	*Percentage recovery*
6.0	28.5
8.0	27.5
10.0	26.5
12.0	24.5
14.0	21.5
16.0	15.0
17.0	7.5
18.0	0.0

In general, where measurements of flow in hatchery troughs have been made by the author, the amounts are more than the rate esti-

mated by the men working in the hatchery, and rates of 16 to 18 gallons per minute appear to be in general use unless a shortage of water exists. Under these conditions, it can be seen from the above table that very low recoveries of oxygen are to be expected with a direct flow from the upper to lower trough.

Accurate determinations of aeration efficiency in hatchery troughs is somewhat difficult as conditions change rapidly and representative

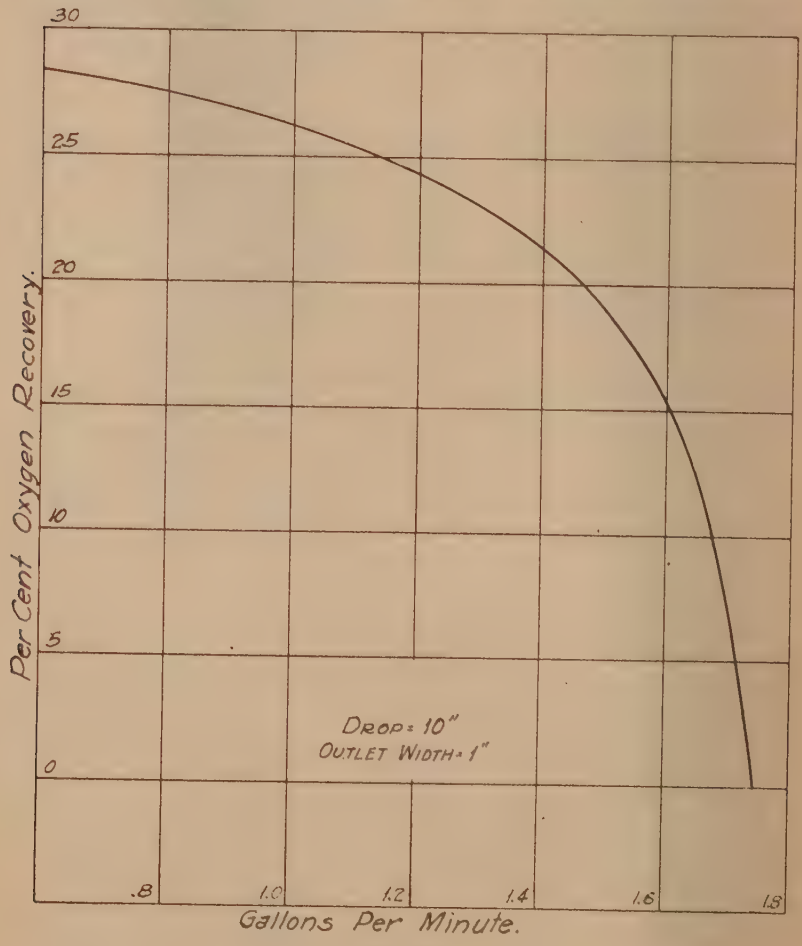


FIG. 48.

samples can not easily be collected. However, tests made in Hatchery B at Mt. Shasta were in general agreement with the above table, the recoveries varying from 8 to 10 per cent. These values apply to both a direct fall and to the present installation consisting of a metal strip having an outward bend at the bottom which has the effect of forming a thinner water film but prevents free access of air on the

back side of the water fall. With oxygen depletions of 33% or about 3 parts per million the actual recoveries were therefore only 0.24 to 0.30 parts per million.

BOX TYPE AERATORS WITH PERFORATED BOTTOM

The box type aerator, of metal, 10 to 12 inches long, 4 to 6 inches wide, 2 to 3 inches deep, and with the bottom perforated with holes of various diameter, is in general use in California. The question of whether the aerator is more effective with holes of small diameter or large diameter has been a matter for considerable discussion.

Surface Exposure.

Table 3 indicates the approximate number of perforations required for a maximum flow of 20 gallons per minute for holes of different diameter and gives the rate of flow for each size, together with a column showing the total surface exposure and a final column giving the necessary width for a single outlet of equivalent surface exposure.

TABLE 3

Diameter inches	*Number of holes*	*Gallons per hole*	*Surface exposure inches*	*Single outlet width equivalent exposure*
1/16	1024	.02	192	96
3/32	455	.045	128	64
1/8	256	.08	96	48
1/4	64	.32	48	24
3/8	28	.72	32	16
1/2	16	1.28	24	12
1	4	5.12	12	6
2	1	20.48	6	3

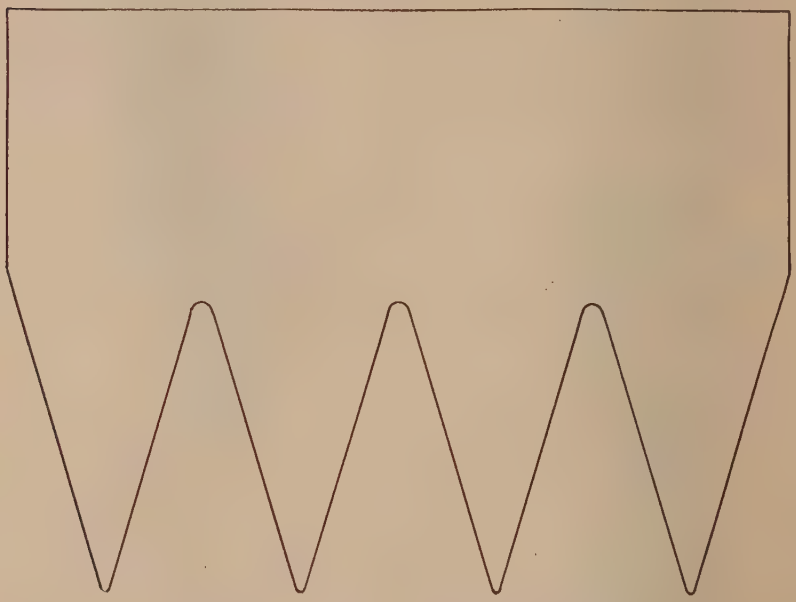
The number of required perforations is inversely proportional to the square of the diameter and the surface exposure inversely proportional to the diameter.

It will be noted from the table that a perforation of $\frac{3}{8}$ inch diameter will carry a flow of about .72 gallons per minute which according to Figure 48 should give an aeration efficiency of 28 per cent with a ten inch fall. The fact that greater volumes of water through the trough outlet resulted in a marked drop in aeration indicates that holes of a larger diameter than $\frac{3}{8}$ inch would have the same effect. Figure 48 in a similar manner indicates that holes of smaller diameter than $\frac{3}{8}$ inch will increase the aeration only moderately.

For experimental tests, outlets of $\frac{3}{32}$, $\frac{1}{8}$, $\frac{1}{4}$ and $\frac{3}{8}$ inch diameter were used. The data from a series of tests with these outlets indicated that aeration increased with decreasing size of outlet; the differences, however, were small except for the $\frac{3}{32}$ inch outlet which showed a marked improvement over the $\frac{1}{8}$ inch outlet. The benefit to be derived from small outlet perforations was more apparent for short falls of 5 to 7 inches. With greater falls than 10 inches the differences became less and the $\frac{3}{32}$ inch outlet was the only one giving a significant improvement in aeration. For falls of 30 inches there was a slight indication that outlets of larger diameter would be preferable.

The aeration efficiency of the smallest outlet was 30 to 32% for a ten inch fall. However, the use of $\frac{3}{32}$ inch perforations is impractical due to the rapidity with which they would clog. A perforation $\frac{1}{8}$ inch in diameter is believed to be the smallest practical size. Tests of a

hatchery aerator with 250 $\frac{1}{8}$ inch holes gave an efficiency of 24 to 26 per cent. In making this test the back side of the aerator was cut down in order to allow the bottom to be placed level with the trough outlet, thus utilizing the full benefit of the 10 inch fall.



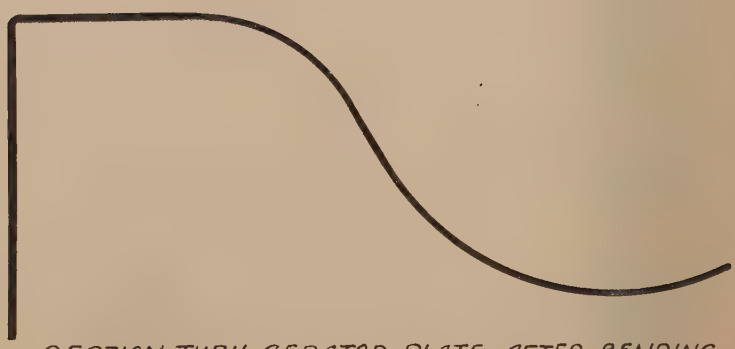


Fig. 49.

Penetration

The problem of distinguishing between the amount of oxygen absorbed in the air, and that absorbed as the stream penetrates the main body of water is difficult to determine. Velocity increases with distance of fall making penetration more effective provided sufficient depth of water is available. A ¼ inch stream of water falling 25 inches picked up only 78% as much oxygen with 1½ inches of water depth as it did with 4½ inches depth. A 3/32 inch stream falling the same distance picked up 92% as much with 1½ inches as it did with 4½ inches depth. The penetrating effect, therefore, depends on cross section as well as velocity. In general, air bubbles carried into the main body of water appear to be relatively ineffective unless of very small diameter, and it is probable that the air carried in as an invisible film surrounding the stream of water is the principal source of aeration resulting from penetration.

Table 3 indicates that a stream of water ⅜ inch in diameter has the same total flow but only ⅓ the surface exposure of 9 streams ⅛ inch in diameter. The fact that the smaller streams absorb only a little more oxygen than the larger stream indicates definitely that penetration is a factor of major importance to be considered in aerator design.

Since penetrating power is important in securing efficient aeration it should be obvious that any object breaking the water velocity above the water surface will result in lowered aeration. This condition exists when box type aerators are installed with the bottom 2 to 4 inches below the level of the trough outlet. It has been shown previously that practically no aeration occurs in the first three inches of fall, and with the velocity broken at this point the effective height is only 7 inches. A comparative test with the same aerator placed three inches below the outlet as opposed to level with the trough outlet indicated 70% as much aeration. The reduction is considerably more when aerators with larger perforations are placed in such a way that the effective drop is only 6 to 7 inches, and it is doubtful whether the average box aerator in use will have an aeration efficiency of more than 10 to 15% as they are now installed.

INTERRUPTED FALL

In some instances a slanting baffle has been placed near the water surface to form a spray and apparently carry more air into the water. Here again the broken water velocity will cause a marked decrease in absorption of oxygen. A comparative test with a baffle so installed as opposed to a direct fall indicated a 50% reduction in aeration.

The use of an inclined plane, either smooth or with a riffle effect will also provide less aeration than can be obtained with a straight drop. Tests of this type with a smooth and a riffled slope four feet long and a total drop of 10 inches showed aeration efficiencies of 18 and 27 per cent and in both instances the flow was only 0.53 gallons per inch of width which for a hatchery trough would require a sloping baffle 36 inches wide and four feet long.

The only position in which a baffle may be placed with beneficial results is at the full height of the water flowing over the edge of the trough outlet. Placed in a vertical plane about 1 inch in front of

the trough outlet and extending down 1 to 2 inches below the level of the outlet, such a baffle has the effect of spreading the water to a thin film giving a greater surface exposure than can be secured with perforations of the smallest practical diameter. In this position the film is directed straight down and the velocity is not broken.

Due to surface tension, the edges of a water film falling from this type of baffle tend to converge, and by varying the flow, the film of water can be controlled to converge to a point above the water level, just at the water level, or to strike the surface without converging to a point. Experimental tests to determine the absorption efficiency under these conditions were conducted. With a volume of 1.5 gallons per minute the spread at the top was 4½ inches and the film converged to a point in 10 inches or just at the water level. Surface exposure in this instance is the equivalent of passing the flow through perforations $\frac{3}{32}$ to $\frac{1}{4}$ inch in diameter, and at the same time, a high degree of penetration is secured as the flow hits the water surface in a small cross section area. Aeration efficiencies under these conditions was 35–42 per cent, the highest values obtained in the experimental work for a 10 inch drop. Decreasing the flow to 0.9 gallons per minute, the film converged and respread above the water level and aeration was reduced to 26 per cent. With a flow of 2.2 gallons per minute the edges of the film remained almost parallel, giving a greater total surface exposure but less penetration, and the aeration efficiency was 21 to 23 per cent.

While baffles at intermediate positions tend to decrease aeration, it is possible to secure an improvement by using intermediate receivers of sufficient water depth to obtain a series of penetration effects. However, the outlet from each such reciver must be at the water level in that receiver so that the sum of the individual falls is the same as for a single fall. Table 4 has been computed from Figure 47 and indicates the probable recovery for a varying number of steps in a 40 inch fall using intermediate water receivers.

TABLE 4

Fall in inches	*Per cent efficiency*	*Efficiency per inch*	*Number of steps*	*Total per cent recovery*
4	7	1.75	10	52
5	12	2.40	8	64
8	22.8	2.86	5	72.5
10	27.5	2.75	4	72.4
20	40.0	2.00	2	64.0
40	53.0	1.33	1	53.0

It will be noted that the highest efficiency is obtained with steps having an 8 inch fall. This would indicate that for the above conditions it would not be desirable to have more than a single step for trough aeration with a 10 inch drop. However, the above values should not be considered as fixed, as the height of the most effective drop will vary depending on the diameter or width of individual outlets, and will vary with the depth of water in the intermediate receivers. It is quite possible that with sufficient depth for penetration and the optimum size of outlets that a single fall of 40 inches would show a higher recovery than is indicated in the above table for a divided fall.

IMPROVED AERATOR DESIGN

The foregoing discussion of factors affecting aeration efficiency indicate that an aerator should be designed to give a high surface exposure and at the same time maintain penetration effect. Needless to say, a large number of aerators were constructed and tested in an attempt to meet the above conditions. A description of those that were tested and finally discarded would appear to be unwarranted. A number were constructed in an attempt to obtain the exact effect for a full hatchery water flow as had been obtained with a flow of 1.5 gallons per minute against a baffle placed at the full height of the outlet. This would require 10 to 12 outlets through the side rather than the bottom, separated so that each would have 5 inches of width in which to spread on a baffle. One aerator giving this effect gave an aeration efficiency of 30 per cent but the aerator would have been relatively expensive and somewhat difficult to scrub and keep clean.

FIG. 50. Improved aerator in operation.

The design that has been tested and selected as the most suitable both from the standpoint of efficiency and simplicity is cut and bent to the proper shape from one piece of metal. Briefly, the water flows through a trough outlet 12 inches wide on to a metal strip having 4 teeth 3 inches wide and 4½ inches long. The teeth are bent downward to give the aeration effect desired. The water spreads as a thin film over the four teeth, giving a surface exposure of approximately 72 inches as compared to 24 inches if the water merely flowed over the 12 inch outlet. With the teeth bent to the proper curvature the water spreads uniformly on the edge of the teeth, and at the same time tends to converge on approaching the water level, giving good penetration and carrying in air between the converging films. The general effect is a large saw tooth edge with a continuous, but converging, cup-shaped film of water downward from the teeth. The aerator is designed to fasten to the inside of the trough partition, being bent at a right angle through the trough outlet, and with the teeth bent to the correct curvature Figure 49 shows the shape of the

aerator as cut from a metal sheet, and an end view showing the manner in which it is bent. The photograph (Fig. 50) shows the aerator in operation in a hatchery trough.

Tests of this aerator with a flow of 18 gallons per minute indicated a recovery of 30 per cent. In two instances the recoveries were 34 and 37 per cent. The aerator will be effective with flows ranging from 10 to 24 gallons per minute, the efficiency probably increasing with decreased flow, but a thorough check of efficiency with varying rate of flow has not yet been obtained. This type of aerator is to be installed in the new hatchery at Basin Creek where a thorough trail of its value will be made.

It is believed that this aerator will average to give 30 per cent recovery as against approximately 10 per cent for the average type of aeration now in use. In general terms, with the new aerator, the lower troughs may receive an additional load equal to 20 per cent of the fish in the upper trough and still maintain the same oxygen content at the outlet of the lower trough. Expressed in another way, the load in the upper may be increased 28.6 per cent and the final oxygen value from the lower will remain the same as it would with aerators of 10 per cent efficiency. With the same loads of fish in the upper and lower troughs the volume of water may be decreased to 90 per cent of the former flow and still maintain the same outlet value. With the same volumes and load the final oxygen depletion should be 10 per cent less with the new aerators.

THE WILD FOWL SANCTUARY AT LAKE MERRITT, CALIFORNIA

By M. Hall McAllister

Lake Merritt, a body of water of about 100 acres, lies within the limits of Oakland, the third largest city in California. The lake was originally an inlet from San Francisco Bay. The water is salt, and is controlled by flood gates with the rise and fall of the tides. It is deep enough for row boats and small pleasure launches. The shores are parked with grass lawns, flowers and shrubs. The north part, of about 10 acres, is wired off and reserved exclusively for wild fowl, no boats being permitted.

Every fall migratory ducks arrive and spend the season between September and March. They are regularly fed twice a day by park attendants. Many visitors also feed the birds, which become very tame and will follow those who throw feed to them.

The canvasbacks differ from the other ducks in that they do not come to the shore. They are fed from a small boat, which paddles out to them. The few mallards remain throughout the year, and breed on a small bush-covered island which is reserved for them.

A number of wire-covered pens have been built, with large open doors, and the ducks are fed in these from time to time. The doors of these pens may be closed so that the ducks may be caught with hand nets and banded. Observations of these banded birds have shown that many of them return year after year.

The Audubon Association of the Pacific has made two counts of the ducks—one in 1923 and another in 1936. These counts show that the diving ducks have increased in number, while the marsh ducks, widgeon and sprig, have decreased. The following table gives the result of the census:

Species	*1923*	*1936*
Canvasback	1,400	1,872
Mallard	100	12
Sprigtail	650	202
Widgeon	430	108
Teal-green wing	6	---
Spoonbill	86	---
Blue-bill-scaup	140	504
Ruddy duck	125	571
Red-head	---	7
Buffle-head	33	---
Golden-eye	26	---
Mud-hen	400	increased

The wild mallards have mated with domestic ducks, and these have been caught at times and sent to charitable institutions. The other wild ducks have not been molested at any time except for the banding.

NOTES ON THE 1930 CATCH OF KING SALMON IN KLAMATH RIVER

By JOHN O. SNYDER

The migration of King Salmon into Klamath River in 1930 presented an unusual departure from what was previously regarded as a normal size and age group representation. Very small fish were so out of proportion in numbers as to attract the attention of even casual observers. The small fish referred to are known to anglers and market fishermen as grilse or chubs. As a matter of fact they are males, two or three years of age and sexually mature. Grilse will grow no larger, but die after spawning as do all salmon. Three-year females occur in numbers in the Klamath catch, but they are much larger than the males, often comparing favorably in size with the smaller four-year fish.

For several years prior to 1930, the Klamath migrations had been rather carefully observed, mainly through the commercial catches, and we had come to regard the age group representations as fairly constant.* It was found that while three-year fish contribute 11 to 15 per cent of the catch, four-year fish constitute the bulk, 63 to 78 per cent. Five-year fish are much less numerous, 10 per cent or more, while there is a small scattering of six-year individuals.

The Commission had an observer, Carleton Rogers, stationed at the mouth of Klamath River during the season of 1930. He examined 1872 fish, so chosen from day to day as to be typical of the catch. They were measured, recorded as to sex, and scales from each were preserved. Later, the writer determined the respective ages of these fishes and reported on the same.†

It appeared that approximately 9 per cent of the catch were two-year fish; 49 per cent were three-year fish; 39 per cent, four-year and but 3 per cent were five-year fish.

In casting about for some explanation for the seeming peculiarity of this particular migration, four assumptions presented themselves:

1. Resulting from an increased demand, smaller fish have been accepted by the dealers, and fishermen have employed nets of a smaller mesh in an effort to take them.

2. A swing in the pendulum of variation for which we are unable to assign a probable cause, and which will eventually right itself.

3. The presence of small fish (third-year class) is the result of a particularly successful breeding season in 1927 and as a result a phenomenal harvest of four-year fish may be expected in 1931.

4. A tendency to mature at a certain age is inherited, and consequently when selective nets deplete the older age groups, those which mature early are left to propagate in undue proportion; a possible result of depletion which in the end will be deleterious to the stock.

* Fish Bulletin No. 34, 1931, Division of Fish and Game of California.
† Fish Bulletin No. 34, 1931, Division of Fish and Game of California, page 125.

The first assumption was dismissed at the time as no changes in methods of fishing were adopted in 1930. No evidence has appeared in support of assumption 4, and furthermore, that possible danger has now passed with the cessation of net fishing.

Observations since 1930 point definitely to 3 as the explanation and indicate that, when viewed in the proper light, there was really nothing very unusual in the migration of that year, for the season of 1934 was the occasion of a relatively huge migration into the Klamath, thus demonstrating beyond doubt that the large number of grilse of the year before resulted from a particularly successful start in 1927.

In 1930 a rack was placed in Shasta River a tributary of the Klamath, and provided with a valve in such a way as to facilitate the counting of all fish that pass through. A census of each migration for six years is presented, and the relation of the grilse population of a particular year to that of the total migration of a following year is indicated. It appears that due to the predominance of four-year fish in a migration, there exists a more or less definite relation between the abundance of grilse of one year with that of the entire number of the following year.

Assuming that the migration in the Shasta is numerically similar to that of the main river, the prospect for a relatively large migration into the Klamath for 1936 is not very good.

Migration of King Salmon into Shasta River

Year	Large fish	*Grilse	Total	Per cent of Grilse
1930	7,279	12,059	19,338	62.3%
1931	61,807	20,037	81,844	24.4%
1932	29,631	5,058	34,689	17.0%
1933	4,678	6,892	11,570	59.5%
1934	26,873	21,795	48,668	44.7%
1935	64,721	9,816	74,537	15.2%

* Neither in this case nor in the report of the 1930 fish, is the stated proportion of Grilse, i.e., 2 and 3 year fish, accurate. Here, the evidence is visual only, and it follows that many 3 year fish, especially females, are included with "large fish." Also, in the fishing of 1930, many small Grilse escaped through the nets.

CALIFORNIA FISH AND GAME

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CALIFORNIA CONSERVATIONIST

In January, 1936, the *California Conservationist* published by the Department of Natural Resources made its bow to the public. This magazine contains news of interest to everyone dealing with any of the five divisions in the Department of Natural Resources. A major portion of the space in the magazine will be devoted to fish and game.

The purpose of the magazine is to acquaint the public with the many activities of the divisions and give them sound, popular articles pointing the way to proper fish and game management. The *California Conservationist* is a monthly publication and through this medium we will be able to carry the conservation story to the State and the Nation.

California Fish and Game will be the medium of recording all of the scientific data compiled by the Division of Fish and Game, which will be relieved of the more popular type of article, which, in the future, will appear in the *Conservationist*. We expect by this means to make California Fish and Game the outstanding scientific publication on fish and game problems in the United States. For years, it has enjoyed an extremely high rating, and now we will be able to devote more space for scientific material and thereby will put it even higher in its relative position with other publications.—*Herbert C. Davis.*

ROUGH FISH

Several kinds of "rough fish," a designation applied by sportsmen to all fish not desirable as "game fish," occur in the larger river basins of the state. These include various species of minnows, suckers, bullheads, and others. Some of them, the Sacramento pike and the blackfish, for example, enter the markets at times in limited numbers. If one of these were in some other region it might qualify as a game fish.

The ecological relation of these rough fish and game fish is not well known in any case. Some rough fish, the bullheads to be particular, are predators and they may account for the loss of many eggs and young of trout. On the other hand, some of the minnows are herbivorous, and they and their young may serve as food for trout and other game fish.

The appearance of a paper on *Hesperoleucus* in this issue of Fish and Game is timely. It is the first account of the life history of a California minnow, and such an account is the first step in the deter-

mination of just where a species stands in a biological association. It is a long step and we look forward to the time when others of a similar sort may be taken.—*J. O. S.*

SHARKS AND RAYS

"The sharks and rays of California," by Lionel A. Walford, is a new publication (Fish Bulletin 45) of the California State Fisheries Laboratory, which promises to be of popular appeal. This bulletin is in the nature of a supplement to Fish Bulletin 28, "Handbook of common commercial and game fishes of California," by the same author. Both were written primarily to assist fishermen and marketmen in identifying the species encountered so that the official common name for each fish would come into general use and eliminate the rather bewildering confusion that formerly existed in the use of names. The handbook has been well received and has been successful in establishing the official common names, so that this similar bulletin is now issued to include the sharks and rays, many of which were not included in Bulletin 28. Twenty-three sharks and 15 rays are reported and of these 38 species, 20 are fairly common in California waters.

In Fish Bulletin 45, as in Bulletin 28, a page is devoted to each species and presents a photograph, distinguishing characters, notes on distribution, and importance of the species. As an additional aid in identification, each bulletin includes a key to species in non-technical language and so arranged as to be usable by fishermen. An introduction to the shark bulletin discusses food values, uses of skins and fins, directions for preparing shark hides for leather, and a brief account of fishing methods in California and elsewhere.—*W. L. S., February 29, 1936.*

SHRIMPS

An investigation of two California shrimps, sponsored by the California Division of Fish and Game, was carried on by Hugh R. Israel at Stanford University under the supervision of Dr. Frank W. Weymouth and Dr. Willis H. Rich. The results have just been published as Fish Bulletin 46, "A contribution toward the life histories of two California shrimps, *Crago franciscorum* (Stimpson) and *Crago nigricauda* (Stimpson)." This report deals with the two important species occurring in the commercial catch of the San Francisco Bay area. A third species of this region is of little value commercially. The report presents the results of extensive sampling in the various areas, and the careful analysis of these data brings out the essential features in the life history of each species. Both species breed at the end of the first year and the adults disappear from the commercial catch soon after they are one year old. In both species the females grow more rapidly than the males. The eggs hatch in deep water of high salinity in the bay region, the larvae float in the plankton and the post-larval young are found in comparatively shallow water of lower salinity than that in which the eggs hatched. As the young grow they move steadily into deeper water, where they are caught by the commercial fishermen.—*W. L. S., February 29, 1936.*

BLENNY EEL IN SOUTHERN CALIFORNIA

On the morning of January 27, 1936, a commercial fisherman brought to the San Pedro fish markets a blenny eel, *Cebidichthys violaceus*. The fish, 62 cm. in length, was taken on a hand line at San Nicholas Island. Blenny eels are of minor commercial importance in the San Francisco and Monterey fisheries but rarely occur south of Pt. Conception. Hubbs (Mich. Acad. Sci., Papers, vol. 7, p. 368, 1926) records these fish as having been taken as far south as Carpinteria. This record from San Nicholas Island appears, therefore, to constitute a southern extension to the former known range of this species.—*Frances N. Clark, California State Fisheries Laboratory, February, 1936.*

PILOT FISH IN CALIFORNIA

On February 8, 1936, the pleasure fishermen aboard the party boat *Waterwitch,* fishing off Pt. Vincente near San Pedro, were treated to an unusual spectacle. At first when an 8-foot blue shark came around the boat, no one was pleased—it meant only that Captain Bert Robertson would have to get out the shark line and catch it before it broke some of the lighter lines. But, as the shark seized the bait, the Captain noted that three small fish accompanied it and followed its every move in the ensuing struggle. The fish were 9 to 10 inches long and looked like small yellowtail except for their distinctive vertical black and silver stripes. The largest swam around directly under the belly of the shark and the others were alongside, one beneath each pectoral fin. When the shark was gaffed and brought aboard, the little fish followed right up to the boat and waited with what the Captain termed an expectant air. Whereupon, he scooped up two of them in a dip net. The third escaped and was shortly afterward seen accompanying a 3½-foot gray shark. Evidently the smaller shark was not satisfactory as the fish left it after about 10 minutes.

Neither the Captain, crew nor passengers had ever seen the like of the strange striped fish, so Robertson turned the two captured specimens over to the California State Fisheries Laboratory for identification. They proved to be *Naucrates ductor,* the pilot fish of fact and fancy, endowed with wondrous attributes since the days of the ancient Greeks. It is a widespread, warm water species that is frequently found accompanying ships and large fish, usually sharks. Many remarkable tales have been told of the friendship of shark and pilot fish and how the latter even leads lost mariners to shore. However, the little fish probably follow sharks and ships to feed on scraps.

The pilot fish, which is not to be confused with the shark sucker or remora, has been reported very few times from California waters. The last definite record was when one was caught off San Diego in August, 1926. At that time the fisherman reported that a small school was seen, and made no mention of sharks. The pilot fish is a member of the family Carangidae, which includes the California yellowtail, *Seriola dorsalis,* and an interesting parallel can be drawn from the habit of the yellowtail, which at times accompanies (and even harasses) large sharks according to observations by Captain Robertson and others.

An excellent account of the pilot fish may be had in "American fishes," by George Brown Goode (1903).—*Richard S. Croker, California State Fisheries Laboratory, February 17, 1936.*

COMMERCIAL USE OF THE JUMBO SQUID, *Dosidicus gigas*

On the morning of August 6, 1934, much excitement prevailed in the San Pedro wholesale fish markets due to the arrival, at the quay side, of a local ring net boat with 3½ tons of a species of squid entirely unknown to the San Pedro fishermen. These squid, although strange to the fishermen, are not new to science and are described under the name, *Dosidicus gigas*. Occasional specimens have been taken off the eastern coast of Australia and in waters to the eastward, off Chile and Peru, from Southern California waters and from Monterey Bay. Dr. Harold Heath states that about 25 years ago approximately 30 stranded specimens were picked up on the beach along a 10-mile strip of coast between Carmel and Monterey.

With the exception of the giant squid, *Moroteuthis robusta*, occasionally taken off California, *Dosidicus gigas* is the largest squid known to California waters. To signify size and to avoid confusion with the giant squid we have named it jumbo squid. The giant squid can be distinguished from the jumbo squid by the prominent hooks on the clubs of the tentacles. These hooks are not found on either the tentacles or the arms of the jumbo squid. It does have large-toothed horny rings on the suckers of the arms but no true hooks. In life the jumbo squid is reddish brown but after death this color changes to a purplish brown.

Following its initial introduction as a commercial fisheries product, about ten tons of jumbo squid was landed at San Pedro in August, 1935, and a little over two tons in September. Catches were made around the Channel Islands and off the mainland near San Pedro. After the September landings no more catches were made until early May, 1935. At San Pedro throughout the summer of 1935, small poundages were delivered and many more would have been taken had there been a ready market for this squid. It is not as desirable for food as is the common squid, *Loligo opalescens*, but a small, although limited, market is maintained, especially among the Japanese.

The presence of the jumbo squid in considerable abundance in Southern California waters during the summer and fall of 1935 is indicated by the frequent occurrence of these squid in the mackerel catches and by the reports of the fishermen. The squid taken off Southern California varied from two to two and one-half feet in length, whereas adults reach a size of several feet. All individuals dissected appeared to be immature as would be expected from their small size. Late in November, 1935, a boat fishing in waters near San Diego caught the largest squid which has come to our attention in Southern California, an adult male about four feet in length.

No reports of the occurrence of jumbo squid as far north as Monterey were made during the summer of 1934, but since August, 1935, they have been taken in and off Monterey Bay and also 15 to 20 miles northward of Santa Cruz. Many individuals were landed during the fall and winter of 1935 and in the month of January, 1936, at Monterey and Santa Cruz. Most of the individuals were between

three and four feet long. Greater amounts have been landed at Santa Cruz than at Monterey. Most of the Santa Cruz landings have been by sablefish fishermen who caught the squid on long lines baited and set for sablefish. These lines are sometimes fished as deep as 300 fathoms. The fishing is done between Santa Cruz and Pt. Ano Nuevo to the northward. On one occasion, during November, 1935, 100 specimens were landed by one boat. Santa Cruz fishermen have reported that during September and October, while fishing for albacore, jumbo squid were seen occasionally trailing the jigs. This fishing occurred several miles north of Santa Cruz and 10 to 15 miles off shore. During November, 1935, about 1000 pounds of these large squid was landed at Santa Cruz by a drag boat crew that had been fishing a drag net about 6 miles north of Santa Cruz in 110 fathoms of water. About 60 pounds of jumbo squid has been sold at Santa Cruz, and a greater amount has been consigned to San Francisco, but it has not found a ready market. As far as is known, jumbo squid has not been sold for food at Monterey.

At Monterey, during the period, August, 1935–January, 1936, occasional specimens were landed by rockfish fishermen, fishing baited long lines for rockfish. These catches were made in and off the southern portion of Monterey Bay and southward to Pt. Sur in water down to 150 fathoms. On January 15, 1936, 400 pounds of jumbo squid was brought in by a purse seine boat. The catch was made in the southern portion of Monterey Bay. The squid of this catch averaged close to four feet in length, and were sold to the Pacific Biological Laboratories of Monterey, dealers in scientific specimens. A few large individuals have been observed from Monterey cannery wharves, swimming close to the surf.

The jumbo squid is quite versatile. It has been observed swimming inshore, close to the surf, and again some miles out to sea, trailing albacore jigs. It has been caught at the surface of the ocean and again as deep as 300 fathoms, on baited hooks. In Southern California waters, the jumbo squid has been taken for commercial purposes in round haul nets, principally. In the Monterey region, they have been taken chiefly on long lines fished by rockfish and sablefish fishermen, but occasional catches have been made with surface nets and with drag nets. A few Southern California anglers have taken the jumbo squid on hook and line and report hooking and landing a jumbo squid exciting sport—*Frances N. Clark and J. B. Phillips, California State Fisheries Laboratory, February, 1936.*

MARLIN AND BROADBILL SWORDFISH

Of the two kinds of swordfish taken by commercial fishermen in California, the broadbill (*Xiphias gladius*) is by far the more important. In 1935, the landings of this species amounted to 664,000 lbs. as compared to 19,000 of marlin (*Makaira mitsukurii*). There are at least two reasons for the great difference in poundage aside from the unknown factor of relative abundance. The first is that the flesh of the broadbill is far superior in flavor and texture and commands a much higher price. The second lies in the method of capture. Commercial fishermen obtain swordfish by means of harpoons. They have

found that the broadbill is much easier to approach and makes a better target, being less active and relatively wider in the body.

However, the marlin is a great deal more important as a game fish than the broadbill. It is easier to induce this species to take a hook, consequently most big game fishermen concentrate their attention on it. A few wealthy anglers with much leisure time spend their summers trying for broadbill, and a few get their fish each year. Some pleasure fishermen, of recent years, have found broadbill harpooning exciting sport and consequently the take of broadbill by noncommercial fishermen has increased. However, the true sportsmen scorn to harpoon their fish and prefer to angle for marlin.

A large proportion of the commercial catch of marlin consists of fish caught by sportsmen and subsequently sold by their boatmen. There is a growing tendency at present to smoke or freeze the greater part of the marlin catch. The frozen fish is smoked during the off-season. Smoked marlin has become a popular article of trade, proving to be much better than the fresh fish. Consequently, there should be no trouble in disposing of excess catches of this species made by sportsmen during the height of the summer season. The broadbill is sold either fresh or frozen, a considerable proportion being shipped to the eastern United States.—*Richard S. Croker, California State Fisheries Laboratory, February 29, 1936.*

REPORTS

STATEMENT OF REVENUE

For the Period July 1, 1935, to December 31, 1935, of the Eighty-seventh Fiscal Year

Revenue for the Fish and Game Preservation Fund, Current Year:

License sales:		
Angling licenses, 1936	$48 00	
Angling licenses, 1935	132,235 00	
Commercial hunting club licenses, 1935-1936	950 00	
Commercial hunting club operators' licenses, 1935-36	215 00	
Deer tags, 1935	97,310 00	
Fish breeders' licenses, 1935	25 00	
Fish importers' licenses, 1935	10 00	
Fish packers' and wholesale shell fish dealers' licenses, 1935-36	950 00	
Game breeders' licenses, 1935	160 00	
Hunting licenses, 1934-35	22,205 00	
Hunting licenses, 1935-36	146,484 00	
Kelp licenses, 1935	10 00	
Market fishermen's licenses, 1935-36	33,220 00	
Trapping licenses, 1935-36	1,101 00	
Total license sales		$434,923 00
Other income:		
Court fines	$25,564 10	
Fish packers' tax	131,656 15	
Fish tag sales	1,404 06	
Game tag sales	125 88	
Importers contributions	350 00	
Interest on bank balances	4,120 59	
Kelp tax	98 10	
Lease of kelp beds	1,025 60	
Miscellaneous sales	1,863 97	
Publication sales	274 40	
Salmon tax—Chap. 1015-35	3 11	
Total other income		166,485 96
Grand total Fish and Game Preservation Fund		$601,408 96

STATEMENT OF EXPENDITURES

For the Period July 1, 1935, to December 31, 1935, of the Eighty-seventh Fiscal Year

Function	Salaries and wages	Materials and supplies	Service and expense	Property and equipment	Total
Administration:					
Executive	$2,499 96				$2,499 96
Clerical and office	2,760 00	$582 83	$158 43	$86 53	3,587 79
Printing, general		616 19			616 19
Automobiles		269 04	168 24		437 28
Traveling			2,022 40		2,022 40
Postage			2,682 49		2,682 49
Telephone and telegraph			2,185 58		2,185 58
Freight, cartage and express			469 55		469 55
Rent			6,089 37		6,089 37
Accident and death claims			439 20		439 20
Accounting pro rate	5,666 68				5,666 68
Legal			1,105 40		1,105 40
Publicity			1,006 45		1,006 45
Federal cooperation	1,985 14				1,985 14
Printing fish and game magazine		800 55			800 55
Premium on bonds			15 00		15 00
Total Administration	$12,911 78	$2,268 61	$16,342 11	$86 53	$31,609 03
Bureau of Education and Research:					
Clerical and office	$960 00		$97 92	$25 00	$1,082 92
Automobiles		$155 83	95 70	898 78	1,150 31
Traveling			446 26		446 26
Photography			5 03		5 03
Library	780 00	143 98	15 00	100 14	1,039 12
Research	1,200 00	8 96	2 50	29 10	1,240 56
Publicity			83 29		83 29
State fair and other exhibits		113 48	1,274 30		1,387 78
Temporary help	40 50				40 50
Total Bureau Education and Research	$2,980 50	$422 25	$2,020 00	$1,053 02	$6,475 77
Bureau Patrol and Law Enforcement:					
Chief and assistants	$5,550 00				$5,550 00
Clerical and office	2,364 66	$27 54	$19 00		2,411 20
Automobiles		15,378 43	4,454 57	$13,068 02	32,901 02
Traveling			25,635 61		25,635 61
Postage			346 51		346 51
Telephone and telegraph			759 70		759 70
Freight, cartage and express			3 72		3 72
Rent			331 60		331 60
Captains and wardens	94,495 16	250 99	258 43	103 00	95,107 58
Launches		886 67	479 68	269 46	1,635 81
Fish planting	2,292 33	571 06	2,806 15	3 00	5,672 54
Premiums on bonds			362 74		362 74
Commercial fisheries patrol:					
Superintendent	1,380 00				1,380 00
Captains and wardens	6,060 00	3 49	45 74		6,109 23
Launches	5,794 84	2,277 64	2,312 39		10,384 87
Fish cannery inspectors, seasonal	7,382 86				7,382 86
Rent			427 92		427 92
Automobiles		266 64	124 81		391 45
Temporary help	39 03				39 03
Traveling			580 91		580 91
Total Bureau Patrol and Law Enforcement	$125,358 88	$19,662 46	$38,949 48	$13,443 48	$197,414 30
Bureau Commercial Fisheries:					
Chief and assistants	$5,873 68				$5,873 68
Clerical and office	4,800 00	$15 93	$23 51	$81 72	4,921 16
Automobiles		273 08	77 20		350 28
Traveling			3,417 31		3,417 31
Telephone and telegraph			332 15		332 15
Freight, cartage and express			145 64		145 64
Rent			66 99		66 99
Heat, light, water and power			156 46		156 46
Hydro-biological survey, Monterey Bay			500 00		500 00
Research	1,140 00	43 92	23 55		1,207 47
Laboratory	12,214 67	1,823 85	104 67	1,927 40	16,070 59
Statistics		736 62	1,048 39		1,785 01
Temporary help	300 19				300 19
Terminal Island grounds	125 82		159 00	6 76	291 58
Total Bureau Commercial Fisheries	$24,454 36	$2,893 40	$6,054 87	$2,015 88	$35,418 51

STATEMENT OF EXPENDITURES

For the Period July 1, 1935, to December 31, 1935, of the Eighty-seventh Fiscal Year—Continued

Function	Salaries and wages	Materials and supplies	Service and expense	Property and equipment	Total
Bureau Fish Culture:					
Chief and assistants	$3,630 00				$3,630 00
Clerical and office	2,689 33	$41 08	$2 25	$2 10	2,734 76
Automobiles		4,092 50	1,652 39	1,866 89	7,611 78
Traveling			6,195 47		6,195 47
Postage			95 77		95 77
Telephone and telegraph			567 97		567 97
Freight, cartage and express			202 17		202 17
Rent			2,188 24		2,188 24
Heat, light and power			826 93		826 93
Hatcheries	55,513 39	44,133 37	563 79	2,212 56	102,423 11
Fish cars	1,770 00	255 63	2,544 54		4,570 17
Blue printing			43 62		43 62
Cooperative research	261 99	620 05	387 30	21 04	1,290 38
Temporary help	1,336 92				1,336 92
Fish Hatchery assistants—					
Seasonal	13,901 50				13,901 50
Hydraulic engineering	1,200 00	15 61	625 90	14 54	1,856 05
Special field	5,580 00	28 67			5,608 67
Fish rescue	975 16	471 80	1,255 87		2,702 83
Total Bureau Fish Culture	$86,858 29	$49,658 71	$17,152 21	$4,117 13	$157,786 34
Bureau Hydraulics:					
Chief	$498 32				$498 32
Traveling			$73 95		73 95
Total Bureau Hydraulics	$498 32		$73 95		$572 27
Bureau Game Propagation:					
Chief and assistants	$2,550 00				$2,550 00
Clerical and office	420 00				420 00
Automobiles		$513 26	$68 14		581 40
Traveling			1,651 17		1,651 17
Postage			2 03		2 03
Telephone and telegraph			125 78		125 78
Freight, cartage and express			15 55		15 55
Heat, light, water and power			1,011 83		1,011 83
Maintenance	6,681 38	4,697 11	143 57	39 78	11,561 84
Temporary help	670 70				670 70
Quail trapping and expansion of quail program	2,310 00	403 43	592 85		3,306 28
Total Bureau Game Propagation	$12,632 08	$5,613 80	$3,610 92	$39 78	$21,896 58
Bureau Game Refuges:					
Chief and assistants	$4,049 98				$4,049 98
Clerical and office	1,160 00	$18 95		$129 42	1,308 37
Automobiles		220 91	$73 24	21 45	315 60
Traveling			1,576 64		1,576 64
Statistics	649 55	984 92	143 06	569 98	2,347 51
Refuge posting	186 29				186 29
Temporary help, seasonal	1,760 32				1,760 32
Refuge maintenance	3,041 68	727 25	1,714 23	8 17	5,491 33
Total Bureau Game Refuges	$10,847 82	$1,952 03	$3,507 47	$729 02	$17,036 34
Bureau Licenses:					
Clerical and office	$6,334 51	$203 17	$46 36	$189 48	$6,773 52
Printing, licenses and applications		439 45			439 45
Traveling			481 42		481 42
Postage			857 05		857 05
Temporary help	500 32				500 32
Freight, cartage and express			47 55		47 55
Premiums on bonds			987 50		987 50
Identification license buttons		4,401 96			4,401 96
License commissions			27,776 85		27,776 85
Total Bureau Licenses	$6,834 83	$5,044 58	$30,196 73	$189 48	$42,265 62
Total eighty-seventh fiscal year expense paid from support appropriations	$283,376 86	$87,515 84	$117,907 74	$21,674 32	$510,474 76

STATEMENT OF EXPENDITURES

For the Period July 1, 1935, to December 31, 1935, of the Eighty-seventh Fiscal Year—Continued

Function	Salaries and wages	Materials and supplies	Service and expense	Property and equipment	Total
Special Items:					
Claim of Chief Accounting Officer of Department of Finance			$1,516 76		$1,516 76
Support of Napa State Farm			6,387 50		6,387 50
Predatory Animal Control:					
Lion hunters	$2,100 67	$723 08	2,580 00		5,403 75
Predatory animal control			422 00		422 00
Predatory animal hunters and trappers, seasonal	3,200 00				3,200 00
Traveling					
Total Predatory Animal Control	5,300 67	723 08	3,002 00		9,025 75
Total Special Items	$5,300 67	$723 08	$10,906 26		$16,930 01
Total Expenditures for Additions and Betterments:					
Permanent Improvements:					
Construction, improvements and equipment and purchase of game refuges and public shooting grounds, Chap. 341-35		$1,429 43	$378 87	$30,212 41	$32,020 71
Contributions to Employees' Retirement System					7,234 73
Total Expenditures, eighty-seventh fiscal year from current biennium					$566,669 21
Prior Biennium Appropriations:					
Eighty-seventh fiscal year:					
Operating Expenditures:					
Special items:					
California Code Commission expenses, Chap. 645-33			$631 92		
Construction Russian River jetties			224 46		
Total Operating Expenditures, eighty-seventh fiscal year					$856 38
Expenditures for additions and betterments:					
Construction, improvements and equipment, Chap. 278-33	$870 74	$4,691 91	$316 48	$15,519 98	$21,399 11
Eighty-sixth fiscal year:					
Operating expenditures:					
Support				$12,089 25	
Fresh fish marketing				148 79	
Special item:					
License commissions				488 90	
Total operating expenditures, eighty-sixth fiscal year					$12,726 94
Expenditures for additions and betterments:					
Construction, improvements and equipment, Chap. 278-33					500 00
Eighty-fifth fiscal year:					
Operating expenditures:					
Support				85 62	
Special item:					
Claim of Chief Accounting Officer of Department of Finance, Chap. 991-33				35 50	
Total operating expenditures, eighty-fifth fiscal year					50 12
Total prior biennium appropriations					$35,532 55
Grand total proprietary group					$602,192 76

SEIZURES OF FISH AND GAME

October, November, December, 1935

Game:	
Deer	16
Deer head	1
Deer hide	1
Deer meat, pounds	1,237
Doves	149
Ducks	340
Geese	24
Godwit, marbled	2
Grebe	1
Meadowlark	1
Mudhens	11
Non-game birds	49
Owl	1
Pheasant	35
Quail	82
Rabbit	1
Shorebirds	7
Snipe	33
Swan	3
Hunting license	1
Fish:	
Abalone	636
Barracuda, pounds	1,173
Bass, Black	9
Bass, Striped	108
Bass, Striped, pounds	90
Clams	961
Crabs (cooked)	240
Halibut, pounds	400
Live car	1
Lobsters	251
Lobster traps	69
Salmon	30
Salmon, pounds	125
Spears	2
Trout	1
Tuna, pounds	3,151
Angling license	1

FISH CASES

October, November, December, 1935

Offense	Number arrests	Fines imposed	Jail sentences (days)
Abalone; overlimit; undersize	61	$925 00	5
Angling; no license	34	349 00	25
Barracuda; undersize	3	75 00	
Bass, striped; overlimit; undersize; selling in closed season	19	450 00	
Clams; possession fork, possession clams in preserve; overlimit; undersize	58	885 00	262½
Commercial fishing; no license	33	140 00	5
Crabs; undersize	2		
Fishing boat; failure to register; no license	2		5
Fish ladder; failure to maintain	1	100 00	
Fishing; too near dam; too near ladder; closed area	9	120 00	
Fish wastage	3	175 00	
License; failure to show on demand; transfer; making false statement	2	42 50	
Lobsters; undersize	9	210 00	
Lobster trap; closed district	3		
Net; operating in closed district	5	300 00	
Night fishing	10	129 00	½
Pollution	4	50 00	
Reduction; over-percentage sardines	1		
Salmon; closed season; failure to stamp cans; overlimit; clubbing; using gaff hook; selling in closed district	11	315 00	
Sardines; using without permit	1	15 00	
Set lines; closed district	6	165 00	12½
Spears; possession closed district	10	100 00	25
Steelhead; unlawful possession	5		
Trout; closed season	2		32
Totals	294	$4,545 50	372½

GAME CASES

October, November, December, 1935

Offense	Number arrests	Fines imposed	Jail sentences (days)
Bear; closed season	1		75
Deer; closed district; closed season; failure to retain head; killing doe; possession fawn, spike; evidence of sex removed	82	$2,828 50	693
Deer tags; altering; failure to attach; failure to send in; false entries; mutilating	12	240 00	
Doves; closed season; overlimit	15	315 00	
Ducks; closed season; overlimit, selling wild ducks	17	430 00	175
Firearms; discharging in game refuge; possession in game refuge	10	181 00	14½
Geese; overlimit	2	30 00	
Hunting; in game refuge; no license; night hunting	101	1,469 00	510
License; alien using citizen's; issuing juvenile's to adult; transfer of; failure to show on demand	11	200 00	
Non-game birds; killing, possession	29	315 00	12½
Pheasant; closed season	24	675 00	
Quail; closed district; closed season; overlimit; selling without license	21	602 50	
Resisting arrest	1	20 00	
Shooting from automobile, highway, power boat	13	265 00	
Spotlight hunting	15	420 00	70
Miscellaneous game cases	1	25 00	
Totals	355	$8,016 00	1,550

FRESH FISH IMPORTATIONS BY POINT OF ORIGIN* FOR OCTOBER, NOVEMBER AND DECEMBER, 1935

Compiled by the Division of Fish and Game, Bureau of Commercial Fisheries

Species	Gulf of California	West coast Lower California	International waters south U. S. boundary (definite origin unknown)	Mexican mainland Central and South America	Japan	Total pounds
Barracuda		263,210				263,210
Cabrilla	3,643	52,495				56,138
Corbina, Mexican	3,772					3,772
Cultus, Pacific		515				515
Grouper	200	11,208	3 798			15,206
Halibut, California		211,400				211,400
Mackerel, Pacific		3,926				3,926
Mackerel, Spanish		1 984				1,984
Rock Bass		4,363				4,363
Rockfish		32,041				32,041
Sablefish		88				88
Sea-bass, Black	267	245,985				246,252
Sea-bass, Totuava	403,290					403,290
Sea-bass, White		20,261				20,261
Shark		1,736				1,736
Sheepshead		392				392
Smelt		154				154
Swordfish, Broadbill		6,720				6,720
Tuna, Albacore		700			1,692,287	1,692,987
Tuna, Bluefin		17,050				17,050
Tuna, Bonito		1,151,914	71,289			1,223,203
Tuna, Oriental					121,077	121,077
Tuna, Skipjack	117,201	1,006,569	3,689,731	37,939	1,747,359	6,598,799
Tuna, Yellowfin	287,633	461,726	17,493,292	1,996,527		20,239,178
Whitefish		1,421				1,421
Yellowtail		935,703	19,816	73		955,592
Crustacean:						
Lobster, Spiny		370,190	2,973			373,163
Total pounds	816,006	4,801,751	21,280,899	2,034,539	3,560,723	32,493,918

* These importations are included in tables of landings. They include fish caught by California boats in foreign waters as well as frozen fish imported for canning in California plants.

FRESH FISH TAKEN IN WATERS NORTH OF THE STATE LINE BY REGISTERED CALIFORNIA FISHING BOATS* FOR OCTOBER, NOVEMBER AND DECEMBER, 1935

Landed in Region 70, Los Angeles

Species	Total pounds
Cultus, Pacific	469
Halibut, Northern	1,006
Rockfish	539
Sablefish	7,165
Total pounds	9,179

* The California commercial fishing boats have fished north of the state line in the past, landing the catch in California ports, but we have had no means of separating the amounts so taken. A new type of fish receipt provides a place to indicate where the fish were caught and in the future this record should be more complete. The first record of fish from north of the border was shown with the figures for the third quarter of 1935—G. CONNER

FRESH FISH IMPORTATIONS* FROM FOREIGN COUNTRIES FOR OCTOBER, NOVEMBER AND DECEMBER, 1935

Compiled by the Division of Fish and Game, Bureau of Commercial Fisheries

Species	Landed in Region 70, Los Angeles	Landed in Region 80, San Diego	Total pounds
Barracuda	205,434	57,776	263,210
Cabrilla	39,954	16,184	56,138
Corbina, Mexican	3,772		3,772
Cultus, Pacific		515	515
Grouper	10,517	4,689	15,206
Halibut, California	46,000	165,400	211,400
Mackerel, Pacific		3,926	3,926
Mackerel, Spanish	1,984		1,984
Rock Bass	1,131	3,232	4,363
Rockfish		32,041	32,041
Sablefish		88	88
Sea-bass, Black	141,931	104,321	246,252
Sea-bass, Totuava	403,290		403,290
Sea-bass, White	12,796	7,465	20,261
Shark	600	1,136	1,736
Sheepshead		392	392
Smelt	140	14	154
Swordfish, Broadbill	3,214	3,506	6,720
Tuna, Albacore	1,692,287	700	1,692,987
Tuna, Bluefin	17,050		17,050
Tuna, Bonito	608,556	614,647	1,223,203
Tuna, Oriental	121,077		121,077
Tuna, Skipjack	3,060,345	3,538,454	6,598,799
Tuna, Yellowfin	4,608,410	15,630,768	20,239,178
Whitefish	678	743	1,421
Yellowtail	147,359	808,233	955,592
Crustacean:			
Lobster, Spiny	44,506	328,657	373,163
Total pounds	11,171,031	21,322,887	32,493,918

* These importations are included in tables of landings. They include fish caught by California boats in foreign waters as well as frozen fish imported for canning in California plants.

CALIFORNIA FRESH FISH LANDINGS* FOR OCTOBER, NOVEMBER AND DECEMBER, 1935

Compiled by the Division of Fish and Game, Bureau of Commercial Fisheries

Species	Region 10, Del Norte	Region 20, Eureka	Region 30, Sacramento	Region 40, San Francisco	Region 50, Monterey	Region 60, Santa Barbara	Region 70, Los Angeles	Region 80, San Diego	Total pounds
Anchovy				5,875	265		1,760		7,900
Barracuda						16,078	231,722	64,528	312,328
Cabezone				200	1,484	34	147		1,865
Cabrilla							39,954	16,184	56,138
Carp			20,432						20,432
Catfish			152,602						152,602
Corbina, Mexican							3,772		3,772
Cultus, Pacific	10,692	79,401		129,270	35,418	214	536	850	256,381
Eel							20		20
Flounder, Starry		1,304		143,653	3,850				148,807
Flying Fish							208		208
Grouper							10,517	4,689	15,206
Hake				24,202			1,748		25,950
Halibut, California				7,786	6,802	41,377	86,631	192,288	334,884
Halibut, Northern	1,675	88,337		400			1,006		91,418
Hardhead			16,708						16,708
Herring, Pacific		508		254,355	16,550	345		81,219	352,977
Kingfish				53	90,014		108,020	237	198,324
Mackerel, Horse					30,491		1,492,826		1,523,317
Mackerel, Pacific				11,700	2,817,929	24,656	68,374,048	3,109,549	74,337,882
Mackerel, Spanish							1,984		1,984
Mullet							56	3,186	3,242
Perch		417		24,203	1,512	150	24,683	562	51,527
Pike			19						19
Pompano, California							1,852		1,852
Rock Bass						2,033	27,665	25,603	55,301
Rockfish	15,680	34,603		199,944	554,407	80,168	88,086	65,864	1,038,752
Sablefish	734	304,609		49,779	144,913		71,232	88	571,355
Salmon			905						905
Sand Dab				152,827	1,592		1,714		156,133
Sardine			74,830,900	24,836,679	213,742,524	100	60,579,868	5,444,863	379,434,934
Sculpin							14,397	3,258	17,655
Sea-bass, Black						554	143,015	107,772	251,341
Sea-bass, Short-fin								98	98
Sea-bass, Totuava							403,290		403,290
Sea-bass, White					71	12,736	29,238	11,939	53,984
Shark				56,157		7,013	35,800	9,561	108,531
Sheepshead						13,952	68,047	2,037	84,036
Skate				86,986	1,378	910	2,712	2,536	94,522

Smelt		10,813		35,031	48,055	770	105,776	1,416	201,861
Sole	44	50		2,123,397	4,383	137,278	910	147	2,266,209
Split-tail			8,245						8,245
Sucker			15,946						15,946
Swordfish, Broadbill						4,717	54,655	31,872	91,244
Swordfish, Marlin							639	407	1,046
Tomcod				190					190
Tuna, Albacore					336,525		2,206,895	21,053	2,564,473
Tuna, Bluefin						502	24,041	1,031	25,574
Tuna, Bonito					345	841	1,035,118	934,440	1,970,744
Tuna, Oriental							121,077		121,077
Tuna, Skipjack							3,060,483	4,038,687	7,099,170
Tuna, Yellowfin						11	4,609,716	15,692,852	20,302,579
Turbot				11,881	112	1	9		12,003
Whitebait				2,101	575				2,676
Whitefish						1,062	6,851	2,099	10,012
Yellowtail							165,246	829,071	994,317
Miscellaneous fish		3,711	66	41,732	5	151	394		46,059
Crustacean:									
Crab	580	7,800		1,062,706	2,756				1,073,842
Crab, Rock							3,547		3,547
Lobster, Spiny						71,701	156,616	381,035	609,352
Prawn					894				894
Shrimp				562,955					562,955
Mollusk:									
Abalone				5,350	453,250	255,750	425		714,775
Clam, Unclassified							168		168
Clam, Cockle		384		809			7,285		8,478
Clam, Gaper				196					196
Clam, Pismo					9,899	35,930			45,829
Clam, Soft-shell				31,307					31,307
Clam, Washington	33	17,060		219					17,312
Octopus		333		1,765	11,295	61	9		13,463
Oyster, Eastern				115,255					115,255
Oyster, Japanese				77,851	19,700				97,551
Oyster, Native				100	60				160
Squid					127,807		2,745		130,552
Whelks							485		485
Total pounds	29,438	549,330	75,045,823	30,056,914	218,464,861	709,095	143,409,644	31,081,021	499,346,126

* Importations of fresh fish from foreign countries included. See importation tables.

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